Diet and movement of free-living cats in different areas of Canberra, Australian Capital Territory.

A Thesis submitted for the degree of Master of Science of the Australian National University.

by

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Statement of Originality

Except where specific acknowledgment is given, this thesis is my original work.

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Abstract

Diet and movement of free-living cats in Canberra, the Australian Capital Territory were investigated with the hope of adding to and improving on the current ecological knowledge of cats in the A.C.T., hence aid in the management of these cats. Cats from five sites were considered for the diet study, two sites from the urban areas of Canberra and three sites from the fringe areas. Movement investigations considered cats from the urban sites. The methodology for the diet study included analysis of faecal scats and of stomach contents. Significant differences between the diet of cats in the different environments and different seasons were examined by analysis of the results using logistic regression modelling. Radio-tracking was used to follow movement of individual cats, with home range and movement analysed using the 'Ranges IV program. Also, significant differences between the home range areas of cats with respect to season and sex were examined.

Cats were opportunistic in their feeding behaviour with abundance and vulnerability of food being important in determining what the cats took in a given season. Urban cats were commensal, the degree of commensalism varying with the availability of insects and vulnerable mammals. However, fringe cats seemed to rely mainly on hunting to obtain food.

The home range and movements of the urban cats seemed to be influenced mainly by the distribution and abundance of food and also shelter. Also, cats were likely to shift their home range any time there was a change in food distribution. However, if food is so scarce that the available food in the small range to be occupied cannot sustain the cats, these cats were likely to increase their ranges, foraging over a bigger area. However, differences between home range areas of cats of opposite sex were not significant.

For the urban cats, control measures that will employ the use of toxic baits were likely to be most successful during the cold seasons (Winter and Autumn) when there was likely to be increased commensalism.

CHAPTER 1. GENERAL INTRODUCTION

1.1. Introduction

Among the pets kept in the world, cats (*Felis catus*) are much loved, and have been associated with humans for a long time, moving with them to different parts of the world, including many remote islands. Where Man has settled, cats have settled with him. In some places where settlement has been abandoned, the long time domesticated cats have been abandoned too, leading to the establishment of feral cat colonies in such areas. Cats are mainly kept as pets and in such circumstances, usually one cat is desired at a time. Female cats however, if not desexed, produce kittens. These are sometimes taken to animal welfare institutions like the RSPCA in Australia. If not, they may be abandoned and may find their way to the wild. This has resulted in the establishment of cat colonies in such places as abandoned buildings with potential shelter, rubbish tips, and picnic sites with a potential food source in and around towns and cities. In Australia also, however, cats are feral throughout the continent.

1.2. History and distribution of cats in Australia

Controversy surrounds the date and time when cats were first introduced into Australia. One view is that they may have been brought in by early European settlers, and later, were liberated in large numbers to control plagues of exotic herbivores such as rabbits and mice (Jones 1992). But there is some evidence that cats reached inland Australia before Europeans did, possibly arriving in the 17th century on Dutch or Asian trading vessels that ran aground on the West Australian coast (Newsome 1991). However, some Aborigines believe that cats have always been present, or that they came from the west (Burbidge *et al.* 1988). Some of the very earliest Europeans to travel the country (Carnegie 1898, cited in Lundie-Jenkins 1992; Davidson 1905, cited in Lundie-Jenkins 1992; Chewings 1930, cited in Lundie-Jenkins 1992) considered feral cats to have colonised the country independently of humans as they were many hundreds of kilometres from the nearest European outstations.

In Victoria, cat introductions could have occurred as early as 1834 (Anon. 1934, cited in Seebeck *et al.* 1991), nearly 50 years after the first fleet of settlers arrived. Victorian cats were brought as pets but later penetrated the bush and soon became established as feral. Bush penetration is assumed to have been aided by land owners, entrepreneurs, and government agencies, who deliberately moved the cats around the countryside to control the Rabbit (*Oryctolagus cuniculus*) (Rolls 1969).

In the Northern Territory, it is asserted that cats were brought as domestic pets with the construction of the overland telegraph line and have been in the area for at least 100 years, becoming extraordinary colonisers (Johnson 1991). Records of cats in the Northern Territory go as far back as 1883 (Winnecke 1884, cited in Johnson 1991).

The method of cat introduction in the Australian Capital Territory is not known, but it is likely that they were brought as pets by Man as he settled in the area. The abandonment of unwanted cats, together with some cats going astray, led to establishment of feral cat populations.

Whatever the precise date of entry, it is clear that cats have been established in Australia for a long time, and are now widely distributed in most environments. In the Australian Capital Territory, they occur in and near urban areas, in forest, woodland and grassland environments that range from the low altitude Murrumbidgee river corridor to the subalpine woodlands of Namadgi National Park. They also frequent sites such as picnic areas, tips and cleared agricultural areas, as individual concentrations (Osborne and Williams 1991). In Victoria, cats occupy virtually all habitats, and in New South Wales, highest densities of cats are reported in areas adjacent to suburban and satellite developments, picnic sites and dumps, and lowest densities in areas of undisturbed cool-temperate rainforest (Seabrook 1991). In Queensland, habitats such as closed forest, open forest and woodland, grasslands, and arid habitats are known to harbour cats (Gordon 1991).

Cats are capable of surviving in a wide variety of habitats and live independently throughout the year in all parts of Australia. The capacity to capture prey up to its own body size (Newsome 1991) gives the cat the potential for damage to a wide range of Australian wildlife species. For example, it is believed that feral cats are successful predators, capable of killing and eating over 100 native species of birds, 50 species of mammals, 3 species of frogs and numerous species of invertebrates (Potter 1991).

The wide and stable distribution of cats in Australia may be attributed to various factors. The importance that was attached to cats as controllers of species like rabbits and Bettongs (*Bettongia*) may have led to their wide spread (Delroy, *et al.* 1986; Copley 1991; Jones 1992). Rather than stopping the spread of such species, these species' spread may have aided in the spread of cats as the cats exploited them as a major new food source, and used rabbit burrows as day time refuges and breeding lairs. The ease with which cats adapt and switch prey (Newsome 1991) may also be a contributing factor to their wide spread. Furthermore, feral cats do not appear to need fresh water. Food and water may be the same for them so long as the prey is fresh (Newsome 1991).

1.3. How big is the cat problem in Australia?

Cats occur throughout Australia and seem not to be limited by any environmental factors. Overall, the total Australian cat population has been estimated as five to ten million cats (Dickman 1993). In Canberra, measures of the urban cat problem show that in 1990, 1320 cats were destroyed by euthanasia and approximately 1100 were returned to owners or were found homes (RSPCA, cited in Osborne and Williams 1991). However, many cats simply are turned loose, or are abandoned by cat owners, or otherwise do not find their way to RSPCA shelter. Therefore the figures quoted above may be underestimates of the cat problem in the urban areas of the A.C.T. As cats are reported to occur also in places such as tips, cleared agricultural areas and picnic sites, the number of free roaming cats in the A.C.T may be many times more than has been reported for urban cats.

In Victoria, estimates go up to 900 000 owned cats and 300 000 strays (McCrory 1988), and in South Australia, cat numbers range from 0.000 1 per hectare in rural areas to two per hectare in city suburbs (Paton 1991). Estimates show that the greater population of cats concentrate in the urban areas. This may be due to favourable living conditions for the cats, such as easy access to food and shelter in the urban areas.

1.4. Definition

In an ideal situation, domestic cats live with Man, stay at home, and eat food provided by him. However, in other instances, cats go astray or are abandoned in the wild intentionally. They then continue to live and hunt on their own, with occasional dependence on food provided by people especially in the urban areas. These cats have sometimes been referred to as feral cats. However, various degrees of ferality can be recognised, such as the stray which was born in captivity and has reverted to the wild itself, as distinct from cats that were born in the wild.

Controversy surrounds the basis for the definition of a feral cat. Most definitions have assessed the degree of ferality based on what an animal eats. Thus, feral cats have been defined as animals and their off-springs that are forced to secure their own food (Coman and Brunner 1972). However, it is argued that even the most well-fed cat continues to hunt and kill prey independently (Davies 1978; Paton 1991), and the impact of this killing is varied, thus rendering this definition rather meaningless. Therefore, what an animal eats should not be used as a final parameter of whether an animal is feral or not. A more fitting definition of feral cats should therefore be "domestic cats and their off-spring that have reverted to a wild or free-living state" (Tabor 1981).

In this study, feral and stray cats are considered. Diet studies based on fringe environment, considered feral cats, while those based on urban environment considered stray cats.

1.5. Reasons for studying the Cats in the A.C.T

1.5.1. Information gap

There is lack of information concerning the population size and structure of the free-ranging domestic cats, or the potential significance of these felines to wildlife populations in the Australian Capital Territory (A.C.T). Although there is a perception that cats cause harm to native fauna, to my knowledge, there has been no specific study which has attempted to assess the diet and movements of cats in the urban areas of the A.C.T. The A.C.T government is thinking of setting up a cat control policy, but this is made impossible by lack of data on the extent of the cat problem. This study therefore aimed to gain some understanding of the feeding habits of the cats, hence the wildlife species that are being affected. Movements and home ranges of such cats were also investigated to determine the current and likely extent of the problem.

1.5.2. Impact on wildlife

In recent times, the Australian fauna has had an alarming record of decline and extinction. In the arid zones, species such as the Golden Bandicoot (*Isoodon auratus*) and Western Quoll (*Dasyurus geoffroii*) survived well into the 1950s and later before finally succumbing (Burbidge *et al.* 1988). It is believed that feral cats are responsible for the extinction of the South Australian Brush-tailed Bettong (*Bettongia penicillata*) as they were specifically introduced to exterminate the bettongs since they were causing serious problems for the vegetable growing industry on St Francis Island (Delroy *et al.* 1986). The precise mechanisms involved in these declines are not fully understood, yet the status of many species may be far from secure. There is therefore an urgent requirement for research into such rare species and the processes believed to be responsible for their decline or threatening their survival.

Recent events in the Northern Territory have illustrated the serious threat posed to remnant populations of arid zone mammals by the feral cat (Johnson 1991). Programs by the Conservation Commission of the Northern Territory to reintroduce two endangered species, the Mala (*Lagorchestes hirsutus*) and Bilby (*Macrotus lagotis*), have suffered dramatic losses due to predation by feral cats (Lundie-Jenkins 1992). In New South Wales, two of the species shown to be taken by cats are fauna of special concern: Paucident Planigale (*Planigale gilesi*) and Grey-crowned Babbler (*Pomatostomus temporalis*) (Seabrook 1991). In Eastern Australia, tens of millions of native vertebrates are feared likely to fall victim annually to domestic cats (Dickman 1993). In Victoria and South Australia, Paton (1991) showed that on average, 50-60% of cats in the surveyed areas caught mammals, 50-60% took birds, and about a third also caught reptiles.

It has been contended that in Adelaide and Sydney, if cats take as few as 10 birds and 20 mammals per hectare each year, populations within suburban areas will be sustained only by continued immigration from less disturbed areas of surrounding bush, if they exist (Dickman 1993). Most of these estimates are based on well-fed domestic cats that do not need to kill for food, therefore depredation rates and impacts of feral cats that need to hunt for their own food should be expected to be greater.

It is, however, possible that any effect of cats on native fauna has been manifest for a long time. It is contended that several species of small mammals became extinct soon after European arrival in Australia. The Big-eared Hopping Mouse (*Notomys macrotis*) disappeared prior to 1844 from Western Australia, as did the Darling Downs Hopping Mouse (*Notomys macrotis*) from southern Queensland. The Shark Bay Mouse (*Pseudomys praeconis*) was similarly last recorded from mainland Western Australia (Dickman 1993). Also, the extinctions and reductions in range of the Short-tailed Hopping Mouse (*Notomys amplus*), White-footed Rabbit (*Conilurus albipes*), Broad-faced Potoroo (*Potorous platyops*), and the Gould's Mouse (*Pseudomys gouldii*) are said to have taken place just before or just after European settlement, well before extensive land use changes, fire regimes, or liberations of other exotic species had occurred and cats alone were present (Dickman 1993), suggesting that cat predation on Australian native wildlife has long been manifest.

The cat has caused much controversy among conservationists. Conflict between groups in society exists with some believing that cats are being unjustly accused as destroyers of wildlife (Jones 1992), while others believe that cats are responsible for the extinction of species (Seabrook 1991; Strahan 1992), and unless control measures are urgently considered, cats will have devastating impacts on the Australian wildlife.

Opinions on the threat posed and damage caused to National Parks and Nature Reserves by feral and introduced mammals in New South Wales ranked cats as the greatest threat to the preservation of parks and reserves (Seabrook 1991). However, Jones (1992) contended that over much of Australia, the cat feeds on the introduced rabbit, the implication being that, to some extent, one cancels out the other, and therefore, the cat must be presumed to be innocent until proven guilty. Contrary to Jones' argument, the range of the rabbit does not extend into much of northern Australia, and there the cat must feed on native animals, supplemented perhaps by the ubiquitous House Mouse (*Mus musculus*). Furthermore, knowing that mammals as large as brushtail possums (*Trichosurus vulpecula*) and as small as pygmy-possums (*Cercartetus nanus*) are eaten by the cat, it must be assumed that, whether or not it has contributed to extinctions, it must have had a severe impact on natural ecosystems, and therefore an automatic assumption of guilt on the part of the intruder, the cat, makes better biological sense (Strahan 1992). This clearly identifies the need for research on the feeding activities of cats in order to develop proper management strategies for cat control.

The activities and movements of cats may reveal the times when most predation takes place and over how big an area the predation effect is spread. Studies of home range will also show the areas where cats tend to concentrate and these may be used as strategic areas when implementing control measures. If control is to be cheaply and effectively carried out, the times when the cats are most active and their movement patterns should be known. By continually tracking the cats, one may determine such information.

1.5.3. Objectives of the study

The study aimed at providing information on the diet of cats in the A.C.T and to examine relationships between the diet and season, environment, age and sex. To shed more light on the range and movement patterns as exhibited by male and female cats in an urban environment, such patterns were estimated for the urban cats in Canberra. Determining areas where cats mainly concentrate and the local conditions in such areas provides insights into the conditions that attract the cats and also influence their movement patterns highlightingpossible control strategies for such urban cats. Determination of the activity pattern of these cats helps in finding the times when the cats are likely to be mostly vulnerable to control techniques. This study aimed at adding to and improving on the current ecological knowledge of the cats, hence to aid in the management of these cats.

The main objectives include:

1. Foods important to cats in the A.C.T.
   - To determine whether there is a significant difference between commensalism of urban cats and fringe cats.
   - To examine relationships between the diet and season
   - To determine the relationship between diet and environment

2. Home ranges of the stray cats at ANU.
   - To determine whether there are seasonal variations in the home ranges of male and female cats.
   - To determine the relationship between cat movement and food availability.

Chapter 1 is a general introduction, describing the history of introduction and distribution of cats, plus their impact on Australian wildlife.

Chapter 2 reviews existing knowledge on the cat, pointing out the different shades of opinion about it. Chapter 3 describes the methods used in the study. The data collected are presented in Chapters 4 and 6, together with the statistical analyses. Logistic models were used to analyse diet data and estimate relationships. The 'Ranges IV' program (Kenward 1990) was used to analyse the radio-tracking data.

Chapters 5 and 7 discuss the results presented in Chapters 4 and 6 respectively. The study concludes with Chapter 8, a general discussion of results, recommendations of what needs to be done to control the cat problem in the A.C.T, and suggestions for further research.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

The feral cat is known as a predatory, carnivorous animal; although it may resort to scavenging, this seldom occurs (Jones and Coman 1981a), and live prey may be preferred. However, during severe drought, commensalism has been reported (Newsome 1991). It is argued that cats, whether owned or unowned, affect Australian wildlife by predation, by competing with native predators and by acting as a reservoir for diseases or parasites likely to affect susceptible native species (Anon. 1992).

Diet studies show that feral cats kill, eat, and thus subsist almost entirely on small birds and mammals (Dilks 1979; Fitzgerald and Karl 1979; Karl and Best 1982). However, some studies show that they are capable of exploiting a wide range of prey types, and can kill prey up to their own body size, a size range that includes most of Australia's endangered and vulnerable mammal, bird and reptile species (Rose 1975, 1976; Strong and Low 1983; Anon. 1992), therefore potentially posing a significant predatory threat to native wildlife. The impacts of levels of predation on individual species are mostly unknown and very difficult to measure. This is further complicated by the fact that cats also take and destroy eggs and nestlings of many bird species (Anon. 1992).

Cats are also responsible for the carriage and transmission of infective diseases such as toxoplasmosis and sarcosporidiosis, which can debilitate and kill native mammals as well as affect livestock and humans. Marsupials are particularly susceptible to toxoplasmosis (Anon. 1992). However, the impacts of these diseases on native wildlife have seldom been investigated or measured (Anon. 1992).

2.2. Activity, Grouping and Social Organisation of Cats

Among felids, diverse social behaviour has been described (Macdonald and Apps 1978; Izawa 1983; Liberg 1984). The feral cat has a number of adaptations for nocturnal or crepuscular activity, mainly involving hunting and courtship behaviour. These adaptations include large eyes with a high proportion of rods in the retina for better vision in poor light, and an acute sense of smell (Tabor 1983). However, Langham (1992) reported that domestication has modified the behavioural adaptations, leading to increased diurnal activity coinciding with the daytime provision of food by people (Turner and Meister 1988). Furthermore, it is argued that individual differences in activity periods of cats may depend on sex, supplementary feeding and social status as well as on seasonal differences (Izawa 1983; Liberg 1984).

2.2.1. Social organisation

Studies have shown the feral cat to be ecologically flexible in its social organisation, thus providing an ideal model for an examination of the behavioural and ecological adaptation of a species introduced into a new environment (Konecny 1987; Dards 1978; Macdonald and Apps 1978). The social organisation of domestic cats, as revealed by laboratory studies is basically a dominance hierarchy (Baron *et al.* 1957; Cole and Shafer 1966). This hierarchical organisation may be a social adjustment to differences in the local conditions, such as resource abundance and habitat complexity. For example, usually males do not share dens, but barns may be used by dominant males when the resident females are in oestrus (Macdonald and Apps 1978; Langham 1992).

That free ranging cats in urban areas are neither truly pets, nor truly feral (Calhoon and Haspel 1989) is attributed to the fact that they can easily gain access to some substitute food from human beings. Furthermore, cats in towns may not find small animals to hunt as they may be scarce, and therefore, they need to be stealthy in their hunting. To maintain stealth, they are solitary animals (Izawa *et al.* 1982). Almost all wild felids appear to be solitary (Corbett 1978).

Although cats are solitary hunters, they may function as social groups with various stable relationships between them (Macdonald and Apps 1978; Jones and Coman 1982). Small communities may exclude strangers, while maintaining stable relationships between colony members (Macdonald and Apps 1978). With such an arrangement, overlapping home ranges may be occupied by the cats, sharing hunting grounds with neighbouring cats in the surrounding fields, but hunting by themselves (Corbett 1978). The frequency of interaction between colony members may be higher than that between cats living in some other habitats (Macdonald and Apps 1978). However, contrary to Dard's (1978) findings, group formation may not be the prerogative of cats dependent on man.

Though the wild cat may function independently, it is much less asocial than is ordinarily believed. In nature, the wild cat seeks the company of others of the same species, including the domestic cat. In captivity however, a greater tendency towards friendship with relatives than with domestic cats is shown, while towards humans they are less friendly than the domestic cat, and they are extremely nervous and timid, requiring prudent and careful treatment (Bernardino 1978).

The social structure of carnivorous mammals is thought to vary with food supply, access to human habitation, and breeding season (Corbett 1978; 1979; Macdonald and Apps 1978). For farm and urban cats that have alternative food sources available to them throughout the year, their ability to exploit these food sources is reflected in their social organisation. On the other hand, for feral cats that lack adequate alternative food sources, especially in winter when even there is competition for the reduced prey population, their social organisation may be dominated by exclusive territories (Corbett 1978). In most situations however, territoriality may be exercised only for a limited "private area", a zone with couches, shelters, watching, grooming and breeding places, the surrounding areas and hunting territories being shared by several individuals (Bernardino 1978). Breeding pairs may be more aggressive, males setting up territories for female mates and defending them against other males (Layhausen 1979).

Scent marking may be used to mark territories, breeding pairs being more aggressive (Layhausen 1979). Scent marking is an important component of cat behaviour and is carried out by both sexes, but males have a higher rate (Macdonald and Voigt 1985). This may be in the form of urine spray (Page *et al.* 1992), or faeces deposited on grass tussocks or on trails within territories, to act as visual markers reinforcing the presence of a territory holder (Corbett 1978; Bernardino 1978). When outside a "private area", the wild cat may leave faeces unburied, but bury faeces inside its "private area". Furthermore, it may be expected that during the breeding season, close association, with resulting pair-bonding, will occur, especially between adults. However, it has been reported that close association between adults is not confined to the breeding season (Corbett 1978; Dards 1978), and pair-bonding may be observed out of the mating season (Bernardino 1978).

The intensity of territoriality will vary from habitat to habitat, depending on the differences in local conditions that prevail. At high resource levels, there is no benefit gained from territoriality, while at lower levels, territoriality ensures at least minimal energy levels. At extremely low resource levels, territoriality may become too expensive to maintain (Konecny 1987). However, territoriality and dominance hierarchies may be employed by populations of the same species under varying ecological conditions to gain access to resources or space. Differences in resource abundance and habitat complexity may result in slightly more territoriality in one population and a more hierarchical organisation in another (Konecny 1987).

2.2.2. Temporal activity patterns

Studying the activity cycle of an animal may be difficult, as the most satisfactory and accurate results will be obtained only if the animal is not disturbed at all. This may be difficult to achieve if animals are to be studied for a very long time. Studies found that the activity of cats varied with ambient temperature (Fennel 1975; Izawa 1983; Konecny 1983; 1987; Langham 1992; Page *et al.* 1992), the greatest percentage activity per hour occurring near sunrise and sunset, while the least activity occurred near midday when the ambient temperature was highest.

Adult males are more active at night than subadults, and in Summer adults remain in shaded sites to avoid the hot weather, becoming more diurnal in the cooler winter months (Jones and Coman 1982; Izawa 1983; Liberg 1984; Langham 1992). The increased activity of adult males in Autumn-Winter may be due to movements made when searching for oestrus females and defending territories. Furthermore, the activity pattern of cats may be determined by prey activity. In the Galapagos Islands, Konecny (1987) found that the lowest rate of activity for cats occurred near midday when surface temperatures are highest and prey activity is lowest. It is contended that differences in periods of activity depend on prey population density. Feral cats are solitary predators capable of hunting both by night and day, depending on the abundance of prey (Veitch 1985; Konecny 1987).

2.3. Diet

2.3.1. Diet and prey selection

The feral cat is capable of exploiting a wide range of prey types. In Queensland, cats were found to feed on geckoes, skinks, monitor, spiders, birds, green vegetable matter, long-haired rat, house mouse, hopping mouse, rabbit, duckling, skinks, crickets and locusts (Winter and Artherton 1985; Atherton *et al.*, cited in Gordon 1991). Predation on small snakes by cats was reported in Melbourne and Victoria (Kearney, 1992).

On islands, cats have few species of mammals to prey on and may have to adjust to other foods. Where seabirds breed in large numbers, they provide the most important alternative to mammals in the diet of cats (Fitzgerald and Karl 1979; Karl and Best 1982). Karl and Best (1982) argued that the cats on Stewart Island fed mainly on rats and to a smaller extent on birds, probably due to the possibility of rats being more numerous than birds, or because there were no rabbits, or mice on the Island.

In view of the data reported by Coman and Brunner (1972) that most smaller native species have low population densities, and that losses due to predation could cause a significant reduction in such populations, endangered species which already suffer through manipulation of their habitat and the impact of introduced grazing animals could face further pressure from predation by cats.

People tend to believe that cat predation mainly affects birds. Indeed, some studies have reported that birds form an important proportion of the cat's diet. Bayly (1978), in comparing diets of the Red Fox (*Vulpes vulpes*) and the feral cats, found that birds were a significant part of the diet of the cat (35% by occurrence), and the cat appeared to be a greater threat to native birds than the fox. Contrary to the popular opinion, Coman and Brunner (1972) found that although birds were common in all the sampling areas, they were a relatively minor item in the diet. Similarly, Izawa (pers.comm. via A. Newsome, CSIRO Division of Wildlife and Ecology), found birds to be of low importance in the diet of cats in inland New South Wales: presumably, factors such as scarcity and difficulty of capture contribute to their low intake. Also, since cats are able to rip all feathers from a carcass before devouring it, intake of birds may be difficult to monitor by the conventional food habits analysis method, hence the low intake reported (Anon. 1975). Furthermore, it may be possible that smaller feathers are partly digested hence difficult to identify from other remains (Anon. 1975).

Vegetable matter has been reported in the diet of cats. Grass, seemingly part of the normal diet of cats, is mentioned in most food habit surveys (Coman and Brunner 1972; Dards 1981). Its presence has been attributed to the method of capture, as the trapped cats are observed to bite at the surrounding vegetation in an attempt to escape (Coman and Brunner 1972). However, the interweaving of grass with hair and, to a lesser extent, bone in the faeces has been thought to suggest that grass may be eaten in order to help clear the gut (Dards 1981).

The feral cat is an opportunist predator in its selection of prey, and is also occasionally a scavenger. The level of predation on any one fauna species partly depends on its relative availability and relative ease of capture (Corbett 1978; Davies and Prentice 1980; Jones and Coman 1981a; Jones 1992). For instance, studies show that rabbit (*Oryctolagus cuniculus*) is the principle food source for the cats (Coman and Brunner 1971; 1972; Bayly 1976; 1978; Jones 1977, Mahood 1980, Jones and Coman 1981b; Liberg 1984; Triggs *et al.* 1984), but this depends largely on the supply of this prey. Where seasonal shortages of rabbits occur, other prey species become increasingly prevalent in the diet (Catling 1988). Similarly, in New South Wales, during good pasture conditions when the rabbit population was increasing, it was found that rabbits were the major vertebrate prey item, both in terms of percentage occurrence and percentage weight (Catling 1988). Furthermore, on pastoral leasehold land in the Northern Territory, among reasonably dense rabbit populations, food items recorded included species of 5 mammals (2 introduced), 12 reptiles, 4 birds and many insect species. However, mammals constituted the bulk of the diet with rabbit and house mouse comprising the greatest percentage (Strong and Low 1983). In Scotland, studies obtained similar results (Corbett 1979).

These studies clearly demonstrate the importance of availability as a determinant of prey taken by cats. However, the cat may not always take the most abundant prey, but that which it prefers. Furthermore, abundance has to be coupled with vulnerability for a given prey species to be taken by the cats (McMurry and Sperry 1941; Eberhard 1954; Parmalee 1953; Coman and Brunner 1972; Jones 1977; Rose 1975; 1976; Taylor 1979; Jones and Coman 1981a; Liberg 1984; Fitzgerald and Karl 1986; Catling 1988), and where this is not so, cats will readily switch prey.

Contrary to the above observations, although rabbits were observed to be plentiful in Autumn at Purple Downs, South Australia, their percentage occurrence in the diet was low. Similarly, the high population of birds at Purple Downs, South Australia, was not reflected in the stomach contents of an opportunist predator, the cat (Bayly 1976). Furthermore, although after a dry year in the Lyndhurst area, South Australia, bird numbers should be lower than at Purple Downs, there was a large increase in bird material in stomachs, compared to Purple Downs figures (Bayly 1978). These results indicate that, sometimes, the feral cat may not be an opportunist predator, but rather, a selective predator with specific preferences.

The activities of cats may alter the structure of Australian wildlife in ecosystems, affecting the success of recovery programs for many endangered and vulnerable Australian native species. For example, in 1991, unowned cats killed all of the Rufous Hare-Wallabies (*Lagorchestes hirsutus*) released in the reintroduction program in the Tanami desert of the Northern Territory (Anon. 1992). Similarly, it is believed that predation by owned and unowned cats is one of the major causes of death in the only remaining population of Eastern Barred Bandicoots (*Parameles gunnii*) on the Australian mainland, in the municipality of Hamilton, Victoria. Furthermore, in south-western Western Australia, cats are believed to be significant predators of the endangered Numbat (*Myrmecobius fasciatus*), and also, of the vulnerable Greater Bilby (*Macrotis lagotis*) in arid Australia (Anon. 1992).

Cats are also implicated in the decline and extinction of native animals on islands. For example, in Western Australia, they have been blamed for the extinction of the Golden Bandicoot (*Isoodon auratus*) and the Spectacled Hare-wallaby (*Lagorchestes conspicillatus*) from Hermite Island in the Monte Bello Islands (Burbidge 1971). On St Francis Island, off the West Coast of South Australia, the lighthouse keeper's cats are blamed for the extinction of the Island's population of Brush-tailed Bettongs (*Bettongia penicillata*) early this century (Delroy *et al.* 1986; Dickman 1993). Published information based on observation of prey items brought home by owned cats shows that, in Australia, cats kill and eat more than 100 native bird species, 50 mammal species, 3 frog species and a wide range of invertebrates (Anon. 1992).

It may however be difficult to assess the cat's true ecological impact as there are other predators like the Red Fox (*Vulpes vulpes*), Dingo (*Canis dingo*) and feral Dog (*Canis familiaris*), which are also predators of birds and small mammals, and often occur with the feral cat throughout much of Australia. The impacts of the levels of predation on individual species are mostly unknown and very difficult to measure, and this may further be complicated where cats take and destroy eggs and nestlings of bird species. For example, a study of the breeding biology of up to 34 cooperative breeding territorial groups of the Splendid Fairy-wren (*Malurus splendens*) in a woodland-heath area near Perth, Australia found that 65 of 655 known nests and their contents were destroyed by cats (Rowley *et al.*, cited in Anon 1992). From a different perspective, the Bird Care and Conservation Society in the Adelaide metropolitan area received 1070 individual protected birds injured by cat attack alone during 1991. Of these, 85% died of various causes including infection, haemorrhage or stress (Anon. 1992).

Isolating the effects of cat predation on native species from other changes that also affect such species populations, like habitat destruction caused by clearing of native vegetation, particularly for agriculture, may be difficult. Coman and Jones (1981) contended that native wildlife contributes only a small part to the diet of feral cats. Furthermore, there are many unaltered habitats where feral cats have been present for probably 100 years or more, and a rich diversity of native fauna still exists (Strahan 1992). Predation itself may not cause a species to become extinct, but it may affect the density and size, or age structure of the prey population (Jones 1992). Although uncertainty exists as to whether destruction of wildlife can be blamed only on the feral cat, it should be noted that the cat is one factor among other threats, such as the fox and vegetation clearance that lead to these extinctions (Anon. 1992).

2.3.2. Energy requirements and predation

Estimates of energy requirements for cats show that adult cats will consume 5-8% of their body weight in prey per day; sub adults will eat 9.5%, and females feeding kittens, 20% (Scott 1972; Jones 1977). Females require a greater daily food intake in the second half of pregnancy, especially during lactation (Fitzgerald and Karl 1979). Therefore, at such times, they should consume more prey than non-expectant females, and may need about 2.5 times the energy of non-breeding females (Konecny 1987).

With such an amount of energy required to sustain the daily activity of cats, predation rates ought to be high. If predation on one single prey species cannot satisfy the energy requirements of the cat, a wide range of fauna ranging from animals the size of a Rufous Hare-wallaby down to insects may be taken (Lundie-Jenkins 1992).

Predation estimates indicate that on Macquarie Island ~~islands~~, 375 cats effect an annual toll of 56 000 rabbits, and approximately 1.22 million birds which may include 47-000 Antarctic Prion (*Pachyptila desolata*) and 11 000 White-headed Petrel (*Pterodroma lessonii*) (Jones 1977; Leader-Williams and Walton 1989). The average domestic cat is estimated to kill 30 vertebrates per year (Paton 1991).

On the Australian mainland, it is estimated that 50 to 60% of domestic cats kill birds, 50 to 60% kill mammals, and a little over 30% kill reptiles (Paton 1991). However, such estimates may certainly be underestimates of the numbers taken as cats may return with only about 50% of their prey. Furthermore, since these are estimates for domestic cats that are well fed by their owners, for feral and stray cats that have to hunt for their own food, numbers may be much greater than this.

Although the figures presented for predation by cats may be alarming, it may be that such figures correspond with the surplus population of the specific prey species which would otherwise die irrespective of predation by cats. That is, they do not necessarily indicate that cats have a significant impact on prey populations.

2.3.3. Food response in relation to season

Seasonal variability in diet of cats has been reported, but only a few studies provide much detail. Due to different breeding cycles for the different prey species, coupled with varying environmental and habitat conditions, a great variability of seasonal patterns of prey species can be expected. Some prey may be strongly seasonal in availability at one locality but not at others, and at one locality, some species may be strongly seasonal and others not. Such prey fluctuations ought to affect the dependence of the opportunist predator on any of such species.

Large fluctuations in the population of any given species may result in the cats eating such species irregularly, with most predation occurring at times when abundance of such a species is high. For instance, house mice were important prey of Californian cats from late Autumn to early Spring (Hubbs 1951), but were taken regularly throughout the year in Australia, Sweden and New Zealand (Fitzgerald and Karl 1979; Liberg 1984; Jones and Coman 1981a). Similarly, rabbits are mostly preyed on in Spring and Summer, when young ones are expected to be abundant, and least in Winter (Fitzgerald and Karl 1979; Jones and Coman 1981a; Liberg 1984).

The breeding season coinciding with the season may also enhance cat predation on such species (Fitzgerald and Karl 1979). For instance, possums are eaten mainly in Winter and Spring when the young may be fending for themselves and so may be particularly vulnerable to predation (Fitzgerald and Karl 1979). Furthermore, as availability of most prey is reduced in winter or drought, dependence of cats on such prey should be reduced, and other alternative foods sought. The cat may therefore become increasingly commensal (Newsome 1991; Tabor 1981) or depend heavily on carrion (Catling 1988; Jones 1977).

2.3.4. Diet response in relation to habitat

Cats in different environments in the USA, Europe, Australia, and New Zealand respond to different food resources in the same manner. In urban areas, there is usually plenty of garbage with food scraps, hence cats may largely depend on garbage (Jackson 1951; Eberhard 1954; McMurry and Sperry 1941), with rodents, especially rats, forming most of the remaining food. Furthermore, in most urban areas, there is usually a large number of people who feed the cats. It is reported that elderly women, spending far more than their pensions will allow, support colonies of cats on a greater variety and amount of food than many domestic cats could ever aspire to (Tabor 1981).

Comparing the diet of house and feral cats, on farmland, the diet may be similar for both house cats and feral cats, but the former may eat more household food scraps and fewer lagomorphs (Liberg 1984). As household food scraps and garbage are more abundant around residential areas but least around non-residential areas, cats from residential areas may feed more on household food scraps and handouts than those from non-residential areas. In the field, away from towns, mammals, especially rodents and birds, may be more common (McMurry and Sperry 1941; Eberhard 1954).

Around farm buildings, because of storage and other conditions, the rat population could be high, hence forming an important food resource for cats (Jackson 1951; Davis 1957). In agricultural or pastoral habitats away from buildings, cats take a wider range of prey, with mammals predominating. As rodents and rabbits might be in great numbers in such areas, rodents are usually most important, with rabbits next. However, in sheep pasture lands in Australia and New Zealand that lack the diversity of rodents found in North America and Europe, rabbits are most important with fewer rodents taken (Coman and Brunner 1972).

In the forests of Australia (Coman and Brunner 1972), and New Zealand (Fitzgerald and Karl 1979), mammals are the most important prey, native mammals (marsupials and rodents) being the main prey, with smaller numbers of rabbits and house mice. In these areas, birds and ectothermic vertebrates and invertebrates are minor items (Fitzgerald and Karl 1979).

2.4. Home Ranges and Movements of Cats

2.4.1. Definition

A home range is the area traversed by the individual in its normal activities of food gathering, mating and caring for young (Burt 1943; Jewell 1966). Therefore, such an area should account for 95% of the animal's utilisation of its habitat (Jenrich and Turner 1969), with a specified probability of enclosing the animal's present location at any time. However, the home range may vary on a daily, monthly, or yearly basis, and therefore, it must be decided whether or not to include dispersal movements of young animals, migration routes, exploratory sallies, or excursions for mating (Dards 1978) in the calculation of home ranges.

2.4.2. Determinants of home range size

The conditions of the habitat in which the animal lives may determine the home range size of the animal, such that the more favourable the conditions, the greater the density of animals, hence the smaller the home range or territory. When there is abundance of prey, plentiful supply of shelter, and the population density of cats in one habitat is much higher than the population densities of cats found in other habitats, not only will the cats in the former habitat have small home ranges but the ranges of some cats will overlap extensively, females sharing family group ranges (Dards 1978; Tabor 1981). This social grouping in an animal that is usually considered to be solitary may be an adaptation to a favourable environment, with local concentrations of resources.

The distribution of the prey in the habitat, plus the habitat's terrain, influence the movements of the animal, hence the home range size and shape. Fitzgerald and Karl (1986) argued that because cats in the Orongorongo valley, New Zealand fed chiefly on rats and rabbits which were plentiful only in the bottom of the long steep-sided valley, the cats' home ranges were rather linear and more akin to the ranges of carnivores living in the streams and rivers, like the mink (Birks and Linn 1982), than to those in the less rugged habitats. In the Orongorongo valley, ranges of females were about 18 times longer than wide, and of males about 28 times longer than wide. Also, maximum range lengths in a straight line, for the females ranged from 1.89 km to 6.4 km and for the males from 4.75 km to 8.6 km (Fitzgerald and Karl 1979).

Concentration of food supplies from houses or garbage dumps may lead to cats keeping permanent dens (Izawa, *et al.* 1982; Natoli 1985). However, where cats hunt dispersed prey it is not possible to maintain permanent dens hence their home ranges may vary from those with permanent dens, (Fitzgerald and Karl 1979). It is thought that an abundant supply of prey reduces the need for a large home range (Tabor 1981; Langham and Porter 1991). Liberg and Sandell (1988) hypothesised that the home range size of females is determined by food abundance and distribution, and that in the absence of other regulating factors, home ranges of females are just large enough to provide food throughout the year. However, Apps (1986) argued that a rich food supply is a necessary, though not a sufficient condition, for cats to decrease their range size.

Changes in the habitat, including changes in the quantity or location of available food, may result in changes in the home range size and shape of a given animal. In other cases, changes in the use of an area may occur, as animals will concentrate in areas where food resources are concentrated. However, female cats may be very reluctant to leave the areas in which they are established (Dards 1978).

The quality of the habitat also may determine the activity levels required by the animal to satisfy its energy requirements (Konecny 1987). At high resource levels, there may be no benefit to territoriality while at lower levels, territoriality may ensure at least minimal energy levels. However, at extremely low resource levels, territoriality may become too expensive to maintain(Konecny 1987).

Within any given home range, specific areas may be preferred and are intensively used by the cats. In South-Eastern Australia, Jones and Coman (1982) reported that all cats fitted with collars and followed by radio-tracking maintained home ranges and within each home range, particular areas were favoured as daytime refuges. These were invariably areas that provided good shelter, like rabbit warrens, hollow trees or logs or dense thickets. Though such preferences may occur, unpleasant experiences may force the animal to shift its home range. Jones and Coman (1982; 1983) found that the shifts in home ranges involving long distances were a result of "traumatic" experiences when the animals were recaptured for the servicing of the radio transmitters. However, feral cats will remain in a localised home range for long periods once maturity is reached.

Interaction between breeding status and resource availability may result in a wide variation in the home range size of an animal. Females feeding kittens may remain in one place for a longer time than other cats. In New Zealand, Fitzgerald and Karl (1986) found that females with kittens moved over a smaller area, the lengths of their ranges were then 0.25-0.5 the length without kittens. Adult females with kittens (in peak lactating season) may decrease their home range size to contain half the number of preferred prey found during pregnancy, and have least daily movements (Jones and Coman 1982; Iwamoto *et al.* pers. comm. via A. Newsome, CSIRO). Such alterations in the home range may be due to the need to pay more attention to protecting babies from predators than retaining a great prey availability by keeping large ranges. Furthermore, the necessity to return quickly and frequently to their litters to suckle or to bring prey, may be other reasons for the females' small home range size. However, such activities are only possible when prey animals abound (Iwamoto *et al.* pers. comm. via A. Newsome, CSIRO Division of Wildlife and Ecology).

The number of sightings used in the estimation of the home range of a given animal may affect the home range size. When range area (R_{min} and R_{mod}) is plotted against the number of sightings for individual cats, the area increases with increasing number of sightings, the greatest rate of increase occurring over the first ten or twenty sightings (Ables 1969; Dards 1978).

The time when fixes are obtained on an animal may affect the home range size obtained, depending on the activity cycle of the animal. Since cats are mostly active at night, it is contended that nocturnal home ranges of cats are significantly larger than the diurnal home ranges in both sexes (Langham and Porter 1991).

2.4.3. Sex age and home range size

A certain consistency in the findings in regard to the animal's home range size exists, the home ranges of adult male cats being larger than those of adult females and subadult males (Bailey 1974; Dards 1978; Macdonald and Apps 1978; Corbett 1979; Liberg 1980; Jones and Coman 1982; 1983; Konecny 1983; Warner 1985; Fitzgerald and Karl 1986). Home ranges of female cats have been found to vary from an average of 0.84 ha to 170 ha (Macdonald and Apps 1978; Liberg 1980; 1984; Jones and Coman 1983; Konecny 1983; Apps 1986; Fitzgerald and Karl 1986; Iwamoto *et al.* pers. comm. via A. Newsome, CSIRO; Langham and Porter 1991), and, in any particular habitat/area, those of adult males are much larger than those of adult females and subadult males (Fitzgerald and Karl 1986). In reviewing a number of studies of cat populations, Liberg and Sandell

(1988) found that the home ranges of males are, on average, 3.5 times larger than those of females. Some studies however, show that male cats may have home ranges ten times those of females (Macdonald 1981; Tabor 1981). However, Page *et al.* (1992) found no significant difference between the mean home range sizes for male and female cats. In urban areas, range sizes can be much smaller (Izawa *et al.* 1982).

Before producing kittens, female cats may have larger home ranges because of food availability and also, the probability that mothers can have several options of birth place for their young and pick the best. After giving birth however, female cats may have smaller home ranges and spend most of their time in one small area, where there is adequate food and shelter: the number of times they venture away from this 'core area' depends on the temperament of the cat (Dards 1978). Females may be able to maintain smaller home ranges by using their ranges more intensively, eating smaller and more numerous prey, returning frequently to their den to suckle or bring prey (Jones and Coman 1982), but such activities are only possible when prey animals abound. Furthermore, females may allocate more attention to protecting kittens from predators than retaining a great prey availability. Iwamoto *et al.* (pers. comm. via A. Newsome, CSIRO Division of Wildlife and Ecology) found that adult female cats with kittens decreased their home range size in October to contain half the number of preferred prey found during pregnancy (October was considered the probable peak lactating season). Energetically, this seems a large disadvantage because lactating females need about 2.5 times the energy of non-breeding females (Konecny 1987).

The home range size of males may be determined by the density and distribution of females, and the need to maintain reproductive access to females (Harestad and Bunnell 1979; Liberg and Sandell 1988). Adult males tend to occupy exclusive home ranges or territories which incorporate the home ranges of several females that are potential mates, while the male remains dominant (Langham and Porter 1991). In contrast, the home range of sub-adult males incorporates dispersal movements possibly influenced by the dominant male. These movements continue until the young male attains adulthood and occupies a territorial home range (Langham and Porter 1991). Furthermore, since on average, adult male cats have greater size than females, larger home ranges may be required due to their greater energy requirements for their greater size (Harestad and Bunnell 1979). However, although a large home range or territory may correlate with the greater metabolic needs of a dominant male, the behavioural and physiological differences may be more important in evolutionary terms. Those males that can hold a territory large enough to include several mature females may tend to produce more offspring than those with smaller territories (Langham and Porter 1991).

Considering the effect of age of the cats on home range, Fitzgerald and Karl (1986) argued that the home ranges of young males may be more similar to those of females than to those of adult males. This may be attributed to the fact that young males do not disperse from their mothers' home ranges until they are 1-3 years old (Liberg 1980; Dards 1978; 1983), when they may be forced out by other cats in the group (Liberg 1980; Warner 1985).

Also, Corbett (1979) found that young wild cats had significantly smaller home ranges than adult wild cats, and young females held small monthly home ranges which were usually centred on a core area. However, the movements of young wild cats were related to possibilities of interaction with resident adult wild cats.

Kittens usually remain in the nest in which they were born until they are weaned, unless they are moved by the mother (Dards 1978). As they grow older, they become more adventurous and start to explore the area over which their mother, or the group ranges. By the time they are adults (at one year), they have a range the same size as an adult female cat, regardless of their sex. Young females remain with the group into which they were born, but the fate of the young males varies (Dards 1978).

Between the age of one and two years, most males leave the group, probably chased away by the males that visit the core area. Many of these emigrating males die or disappear, the remainder establishing themselves in new areas and develop large ranges and the behavioural characteristics of mature males (Dards 1978). These successful emigrants therefore, have very large cumulative ranges but do not return to their original areas (Dards 1978).

2.4.4. Seasonal changes in home range size

Diet studies indicate that prey availability will be influenced by season, so the movements and the home ranges of the cats ought, too, to be influenced by season. In Scotland, Corbett (1979) found that the largest home ranges for adult females were occupied in late winter and spring when most mating was thought to have occurred. Adult males held ranges similar in size (176 ha) to those of adult females, but they only appeared to be resident in an area during winter and early spring months, which was thought to have been related to bad weather in winter.

Average home range size, based on night fixes, show that females use the largest areas in Summer, which may be correlated with the need to forage further afield to procure food for the kittens (Langham and Porter 1991). However, the larger territories for adult males in Spring and Summer is attributed to their most likely activity of mating and defending females within their territory during that season (Langham and Porter 1991).

2.4.5. Home range size and density

Where food is abundant and den sites common, large cat populations may be attracted, leading to high densities, especially in urban areas where the cat's diet may consist of plentiful supply of garbage, often supplemented by pet food and handed-out food supplies (Tabor 1981). In rural environments however, where cats have to catch a higher proportion of their food, there is less tendency to attract and maintain high populations. Cats therefore may be less abundant, their numbers probably reflecting prey density (Izawa *et al.* 1982). In urban areas, it seems that the abundance of food will allow the cats to reduce their home ranges sufficiently to allow a greater density of cats, therefore, the home ranges may not be a function of the cat population densities, but rather of the food availability (Tabor 1981). Therefore, a negative correlation may seem to exist between home range size and population density of cats although the population density of cats is due to the availability and dispersion of resources (Liberg and Sandell 1988).

2.4.6. Nature of overlap between home ranges

Home range overlaps have been reported for cats of the same sex, for different sexes and for cats belonging to the same feeding group. It has been found that female-female home ranges have the least and female-male home ranges the most overlap (Bailey 1974; Konecny 1987). Also, male home ranges overlap the ranges of one or more females but adult males occupy almost exclusive home ranges with little overlap (Langham and Porter 1991). In England, at the Portsmouth dockyards, most adult female cats were found living in groups, sharing their ranges with one or more females, while adult male cats had larger ranges that covered the ranges of several groups of females (Dards 1978; 1983). It is argued that when the animals have smaller home ranges with sometimes equivalent energy needs, there is a need to select areas of high productivity and to be intra sexually more exclusive, hence the lack of overlap between the ranges (Dards 1983).

Range sizes of groups probably depend on the available resources but are independent of the number of cats in the group. Where cats feed on the same food source, the home ranges of members of the same feeding group may overlap considerably within and between sexes. For cats belonging to different feeding groups, the ranges may overlap very little (Izawa *et al.* 1982). It is suggested that cats that are living in a group and have overlapping home ranges may be closely related (Laundre 1977; Macdonald and Apps 1978; Liberg 1980), and where they are not related, they may have been introduced into the group as 2-3 months-old kittens (George 1978).

In the above literature, differences in predation effects and range patterns of cats are reported. The general thread running through all the data presented appears to be the fact that predation and range patterns are influenced by prey resources, habitat and the age/sex of cats. Therefore, if an effective management approach is to be attained for the cats in any given area, rather than relying on data from previous studies in different environments, good understanding of the ecology of the cats in the area under consideration must be achieved.

2.4.7. Domestic versus feral and home range size

It is argued that home ranges of female cats associated with Man vary from an average of 0.84 ha to 112 ha (Dards 1978; Macdonald and Apps 1978; Liberg 1980; Warner 1985). Among feral cats however, female cats have been found to have home ranges varying from 80 ha to 170 ha (Jones and Coman 1982; Fitzgerald and Karl 1986; Konecny 1983). In all cases, the ranges of male cats are reported much larger than those of females (Dards 1978; Fitzgerald and Karl 1986; Jones and Coman 1982; Konecny 1983; Macdonald and Apps 1978; Warner 1985).

2.5. Disease threat

Cats are of economic significance because they harbour and are susceptible to diseases that are transmissible to other cats, man, livestock and even other Australian wildlife (Proulx 1988). The effect of some of those diseases is only just beginning to be assessed. In the livestock area, toxoplasmosis and sarcocystosis are the most important diseases spread by cats, with rural cats, feral and domestic cats playing the role of the definitive host (Anon. 1992).

In humans, toxoplasmosis is of most serious threat, infants and unborn children having the highest risk, although 30-50% of the world's human population carries antibodies (Jarvis 1990). The toxoplasmosis parasite (*Toxoplasma gondii*) has a fairly complicated life cycle involving a great variety of animals but the definitive host is the cat (Dubey 1986; Passanisi and Macdonald 1990; Obendorf 1992). The nature of the hunting activities and the life style of feral cats renders them more likely to have toxoplasmosis infections than domestic cats (Obendorf 1992), hence posing greater risk of infection to humans, pets, livestock and other wildlife species in contact with feral cats. In Tasmania and Victoria, it is estimated that approximately 50% of unowned cats have blood titres of *Toxoplasma gondii* (Anon. 1992).

Toxoplasmosis and visceral larvae migrans are of concern in urban settings, particularly when cats, whether owned or unowned, defaecate in sand pits and vegetable gardens (Anon. 1992). Humans are exposed through contact with cat faeces. Although the disease may be of little consequence in adult humans, if women are infected during pregnancy, serious illness in babies may result, as babies may be born blind or mentally retarded (Cross, Charles Sturt University, Riverina, pers. comm., 1990). Visceral larvae migrans is caused by the larvae of *Toxocara catti*, a nematode

Introduced rodents, birds and a number of wild animals contain cysts of toxoplasmosis, hence cats may become infected when they eat such infected animal tissue. By the nature of their hunting activities, feral and stray cats are more likely to have *Toxoplasma* infection than domestic cats. Therefore, the escalating number of homeless and unwanted cats throughout Australia pose a significant health hazard. Mortalities have mainly been reported for herbivorous species such as kangaroos, wallabies, and wombats. Nevertheless, carnivorous and omnivorous marsupials have also been killed (Anon. 1992).

In Tasmania, Bennett's Wallaby (*Macropus rufogriseus*), the Tasmanian Pademelon (*Thylogale billardierii*), the Eastern Barred Bandicoot (*Perameles gunnii*) and the Common Wombat (*Vombatus ursinus*) have all developed *Toxoplasma* infections in the wild, and at least four other Tasmanian species are considered equally at risk: the Tasmanian Forester Kangaroo (*M.acropus giganteus*), Long-nosed Potoroo

(*Potorous tridactylus*), Southern Brown Bandicoot (*Isoodon obesulus*) and Tasmanian Bettong (*Bettongia gaimardi*). Furthermore, many species now considered endangered and threatened elsewhere (Parma Wallaby *M. parma*, Mala *Lagorchestes hirsutus*, Kowari *Dasyuroides byrnei*, Yellow-footed Rock-wallaby *Petrogale xanthopus*, Quokka *Setonix brachyurus*, Numbat *Myrmecobius fasciatus*, Bilby *Macrotus lagotis*) are reported to have died from toxoplasmosis in captivity (Obendorf 1992).

Infection of herbivores may occur through ingesting oocysts contaminating pasture, hay, grain or water supplies. In addition, coprophagic and soil-associated invertebrates can act as temporary transport hosts for oocysts. By eating these contaminated hosts insectivorous animals may become infected, while for carnivorous marsupials, infection is likely to be through ingestion of tissue cysts (Obendorf 1992).

In addition to toxoplasmosis, cats may also play an important role in the spread of sarcocystis and rabies which are infectious to humans and wildlife. Sarcocystis is of economic importance as it affects livestock, resulting in the livestock carcasses either being heavily trimmed or condemned (Obendorf 1992). Although cats do not appear to play a significant role in urban rabies, under Australian conditions, it is suspected that feral cats could play a significant part in maintainance and spread of the disease (Anon. 1992).

CHAPTER 3. MATERIALS AND METHODS

3.1. Sites

A number of sites in different environments were considered as possible study sites. These included areas in the urban environment:- The Australian National University (ANU) and Old Parliament House (OPH); fringe areas:-Murrumbidgee River Corridor (MRC), Googong Nature Reserve (GNR), Mugga Lane rubbish tip (ML), the National Exhibition Centre (NATEX) and Mitchell area; the urban-bush interface:- Botanic Gardens, Fernhill park, and the strip between Botanic Gardens and Canberra Nature Park. Six of these areas (ANU, OPH, NATEX, Mitchell area, Botanic Gardens, Fernhill park, and the strip between Botanic Gardens and Canberra Nature Park) were considered for the preliminary survey. However, the final survey for this study considered only the ANU, OPH, MRC, GNR, and ML (Figure 1).

The Mugga Lane rubbish dump (ML) is an area of 140 ha under the management of the A.C.T Government. The dump houses rubbish of which waste such as food scraps comprise a big percentage of the dumped material. Although the dumped rubbish is compacted daily, that dumped in the afternoons is not compacted until the next morning. Scraps are therefore available for the cats to scavenge on in the evenings and early mornings.

Both MRC and GNR are nature reserves. These sites have a few kiosks, picnic sites, and station workshops. There are no garbage bins at these sites. Therefore, people who use the picnic sites are required to take their rubbish home. This means that, apart from a few scattered garbage items that may be left behind by some members of the public, there may be hardly any food scraps around picnic sites and kiosks for cats at these sites to scavenge on.

The Old Parliament House (OPH), though less used than the New Parliament house, is visited by tourists. The site has garbage bins scattered around with no lids. Tourists who visit the site use such bins to dispose of their garbage. Furthermore, the site is in the urban area, it is easily accessed by cat lovers who come to feed the cats in the evening (plate 1). This feeding (plate 2) attracts cats from the neighbouring areas like the War Memorial, the New Parliament House, and the surrounding suburbs.

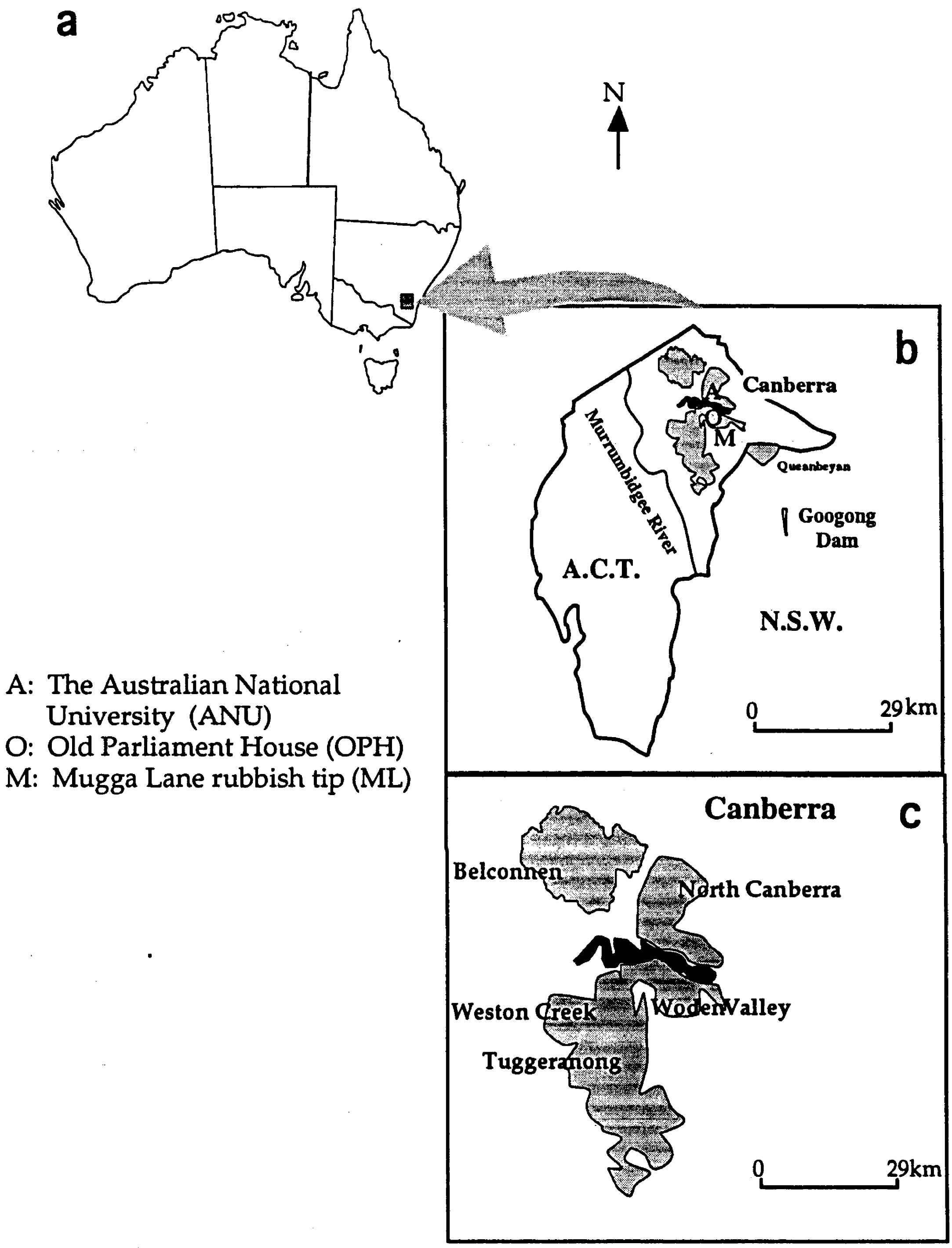

Figure 1. Map showing the location of the study areas. Googong Nature Reserve and the Murrumbidgee River Corridor are shown with full title in map 'b'. The other three sites are represented in map 'b' by letters, 'A' for the Australian National University.

Plate 1. Photograph of lady preparing to feed cats at OPH.

Plate 2. Photograph of food given to the cats at OPH.

The Australian National University (ANU) (Appendix 1) has eating places like the Students Union, Caterinas shop and the gods. There are also residences for students. The ANU also has public eating places in the neighbourhood like the Workers Club which is about 100 m from the ANU, and take-away food outlets. There are garbage bins scattered around the place, from which cats can scavenge on the household food scraps. There are also open public eating places, which have bins for the disposal of garbage. Most of these bins are not fitted with tight fitting lids, and where lids are fitted, they are kept open most of the time. Furthermore, some of the bins are low enough for the cats to jump in, eat whatever they can, and then jump out. As the ANU is next to the city, it is also easily accessed by people who feed the cats.

3.2. Trapping

3.2.1. Traps and baits

Forty (60 cm long, 30 cm wide, 30 cm high) drop-door possum cage traps, each baited with fresh fish were used. The traps were set every day late in the afternoon for four days a week. They were checked soon after dawn, removed and taken back to the laboratory to remove the trapped animals and the baits in the traps, and also to reduce the risk of theft and vandalism. Where it was considered safe, baits were removed and the traps left in place but not set. In the afternoon, the traps were baited again and taken back to the study areas and re-set in the evening.

Baits were prepared by cutting fresh fish into small pieces, which were then put in a piece of body stocking or in a chuck cloth with small holes that allowed the odour to disperse. The stocking/chuck was then tied securely on the hook in the cage trap to ensure that the cat pulled the bait effectively to trigger closure of the trap door. A large batch of baits was prepared at a time and the unused ones were kept in the freezer for later use. Fresh baits were used each trap-night to ensure effective dispersal of the odour. Occasionally, the traps were cleaned with running water to clean out the cat smell and thus reduce the possibility of cats avoiding the traps.

3.2.2. Trapping program

The preliminary survey was from March 1993 to mid April 1993. A questionnaire (Appendix 2) was prepared and distributed to people in the areas where trapping was to be done, to provide an indication of suitable areas for research and study. Six areas, the Australian National University campus (ANU), Old Parliament House surrounds (OPH), the National Exhibition Centre grounds (NATEX), Mitchell area, Fernhill park, and National Botanic Gardens were considered for this survey.

A permit to trap wildlife (F.FOR.14.93) was issued by the Animal Ethics Committee in May 1993. Following this, a preliminary trapping session was undertaken from May 1993 to Mid June 1993, to determine the best sites to work in, the best way of setting the traps and the most suitable baits to use.

From the responses to the questionaires issued, five areas were selected for preliminary trapping. These were the ANU and OPH (urban), the National Botanic Gardens and the strip between the Botanic Gardens and Canberra Nature Park (urban-bush interface), and the NATEX (fringe). Twenty five traps were set in strategic places for three consecutive nights at each site. Two sites were trapped each week.

Conditions of the permit from the National Botanic Gardens to trap in the urban-bush interface areas required that captured cats be destroyed. Cats captured in this area were intended for diet studies only. Intensive trapping had been carried out by the management at OPH and NATEX, with the aim of removing the cats in the areas. The cats were therefore aware of the traps and were trap shy. This, together with the abundance of food handouts provided by cat lovers in these areas, made successful trapping impossible. Furthermore, the areas were inconvenient and quite insecure to work in alone at night. Trapping at the ANU did not give enough cats both for movement and diet studies.

Results from the preliminary survey resulted in trapping for movement and home range studies being concentrated at the ANU, and cats trapped from the urban-bush interface being used for the diet study. The NATEX fringe area was abandoned as a trapping site.

Forty traps were set at random in strategic places that were considered to have high chances of cats visiting the traps at night. These places were identified from the preliminary trapping sessions as areas near garbage bins (plate 3), spaces under buildings, around public eating places and behind bushes. On some occasions, a cat pulled the bait out of the trap without getting into the trap. This was minimised by putting the rear ends of two traps together (plate 4). Traps were put out on alternate days in the trapping sites for sixteen days a month (four nights a week) from

June 1993 to August 1993, and from October 1993 to February 1994, timing the period when cats began to drop litters.

Plate 3. Photograph of garbage bins at the ANU, a potential feeding place for cats, hence good trap spot.

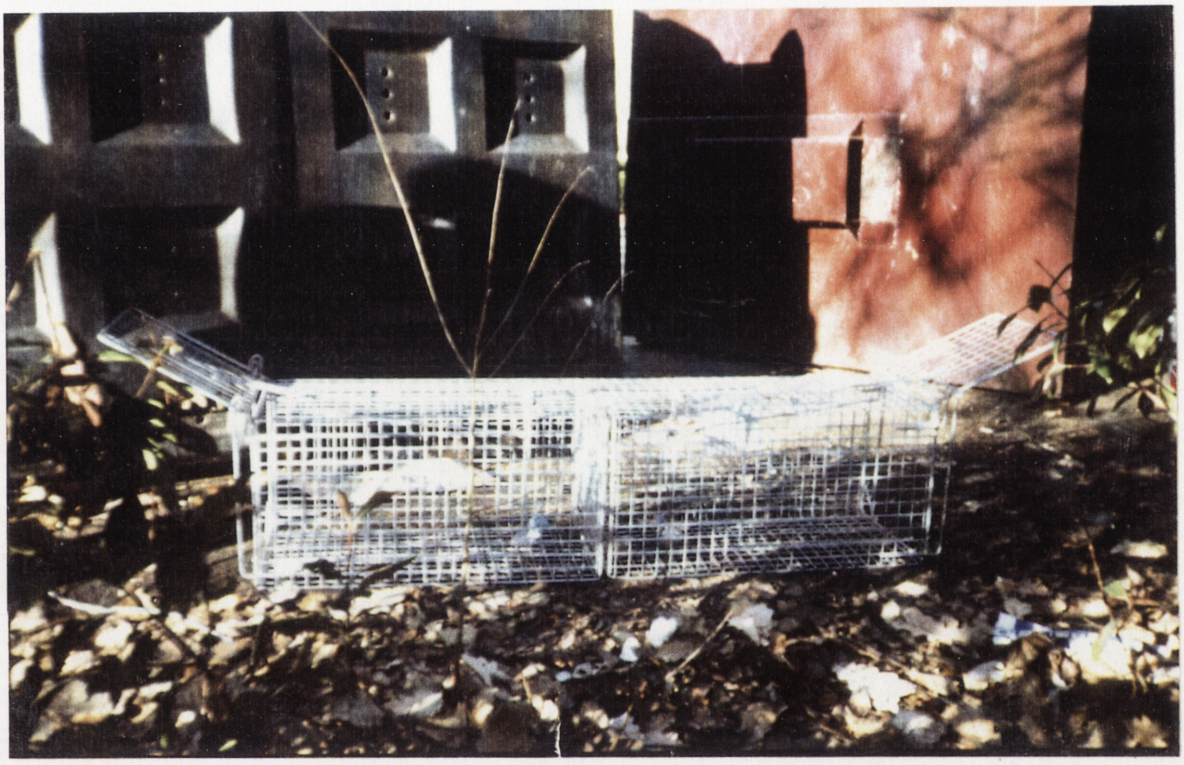

Plate 4. Photograph of two traps set with rear ends together. Containers in background are large garbage bins.

3.3. Age determination, marking and handling of animals

Each captured cat was weighed. To achieve this, the cat and the cage were weighed and the cat was transferred from the capture cage to a restraining cage trap. This had extensions that slid over the outer sides on the cage trap containing the cat, and enabled the cat to be run into the restraining trap without any contact with the investigator (plate 5). Once the cat was transferred into the restraining trap, the empty cage trap was weighed. The weight of the cat was obtained by subtracting the weight of the trap from the weight of the trap plus the cat. It was important to know the weight of the cat so that the correct amount of anaesthetic could be administered.

A sliding panel restricted movement of the cat once it entered the trap. This restraining technique was preferred over the retaining sleeve used in some studies (Fitzgerald and Karl 1986) because it was safer. Furthermore, the sliding panel could be adjusted to press the cat against the mesh on the side of the cage, so that an injection of Zoletil as an immobilising agent could be given.

In most studies, ketamine hydrochloride was the anaesthetic used to immobilise the cats (Fitzgerald and Karl 1986; Langham and Porter 1991). In this study, Zoletil 50 was used and was administered intramuscularly. Zoletil was preferred because it does not give the cats spasms and has a pain-killing effect.

Each cat was then sexed and measurements taken of the head and body length and the tail length. The coat colour, reproductive state, condition of teeth and any injuries on the cat were recorded. Attempts were made to classify cats as adult, juvenile or kitten, and in this case, weight and size, together with the reproductive condition such as pregnancy, lactating and prominent mammaries and nipples in females, were the criteria used for classification.

Plate 5. Photograph of the cage trap with adjustable restraining device to reduce movement of cat.

After administering the anaesthetic and doing the physical examination, a radio collar was attached to each cat to be tracked. A piece of hard cardboard was placed on the mesh which formed the base of the trap, to prevent the anaesthetised cat from freezing due to the cold mesh, and the cat was put back in the cage (plate 6). The cage was then covered with a dark cloth to minimise destruction, and the cat was left to recover from the anaesthetic (plate 7), before releasing it at the point of capture.

Tracking equipment was designed and supplied by Titley Electronics Pty Ltd of Ballina, New South Wales, Australia. The transmitters used in the study were collar type, microlite radio transmitters (Model GPI). Battery life was up to nine months. Each transmitter produced a unique signal, lying between 151.430 to 151.610 MHz. The frequencies were kept 20 KHz apart.

Plate 6. Photograph of cat resting in a cage trap after examination and fitting of radio transmitter.

Plate 7. Photograph of cat in trap after handling and fitting of a radio collar. Note that the adjacent occupied traps are covered during the recovery period.

3.4. Radio tracking and activity recording

Collared cats at the ANU were tracked for 24 hours once every fortnight. A portable hand-held Regal 2000 telemetry receiver, ear phones, a directional antenna and a compass were used to locate the cats. The antenna was connected to the receiver, the signal tuned in, and the receiver was switched on with the gain set low. The volume control was turned to about half the full setting and the antenna was rotated until it gave the strongest signal. The cat was then located by gradually homing in on it.

When the animal was seen, that spot was plotted on the map together with the time at which it was seen and its activity at that time. Sometimes, the cat moved away as it was approached. To minimise the effect of disturbing the animal's activity, as the animal was approached, the gain was set as low as possible, since it was found that after some time, the cats got used to the signal sound and moved away on hearing it.

Because of the presence of buildings in and around the study area, sometimes the signal became attenuated and it was difficult to determine the actual direction of the animal. Furthermore, the cats would hide in the drains or the spaces under buildings, making location difficult. As a result, the time intervals between locations were not equal. However, attempts were made to obtain hourly locations for each cat. Initially, cats were located at regular intervals over 24 hours for two consecutive days, to establish the activity pattern of the animals. After the activity pattern was established, tracking was done once every fortnight.

Initial tracking showed that the cats were more active at night. They tended to remain almost in the same position during the day and were less active so that few locations were obtained. Tracking was therefore concentrated to night hours to maximize the information obtained on the activity and movement of the cats. Cats were tracked throughout the night, with an hourly location for each cat obtained for a 12 hour period.

3.5. Diet study

3.5.1. Collection of samples for the diet study

Samples for the diet study were obtained from five different sites; the Australian National University grounds (ANU), and the Old Parliament House grounds (OPH) (the urban environment), Murrumbidgee River

Corridor (MRC), Googong Nature Reserve (GNR), and from the Mugga Lane rubbish tip (ML) (fringe areas).

3.5.2. Collection of stomach samples

Cats for diet studies were trapped in trials at the Botanic Gardens and the strip between the Botanic Gardens and the Canberra Nature Park. No cats were trapped in the strip. Two cats trapped at the Botanic Gardens comprised too small a sample for the study of the diet of cats in the area.

Stomach and intestine samples were obtained from the A.C.T Parks and Conservation Service. These were from cats trapped in 1992 from the MRC and GNR. More stomach and intestine samples were obtained from cats trapped by another study at ML in 1993.

3.5.3. Collection of faecal pellets

Scats were collected from the ANU and OPH once every fortnight. Scats were commonly found along roadsides, tracks, in the neighbourhood of picnic grounds, near garbage bins, around the bases of trees, and in cleared areas with soft ground. Areas where cats were seen to concentrate during tracking were searched over and over again. In most cases, scats were exposed as groups of droppings and the undisturbed soil or surroundings indicated that no attempts had been made to cover them. A group of scats found was regarded as one scat. Sometimes scats were buried, especially in flower gardens and other cleared areas with soft ground. In such instances, a mound of leaves/soil, or scratchings on the ground were pointers used to determine where the scats were buried.

The cats defaecated in almost the same area each time. Such areas were usually thoroughly searched. Cat scats were mainly identified by their strong smell. Where the scats were so old that the smell could not be used for identification, other features such as shape were used, as cat scats tend to have a more rounded end and a darker colour in comparison to fox scats.

The scats found were put in small plastic bags and taken to the laboratory. Plastic bags were much safer to use as they minimized the chances of getting into contact with the scats. With a hand protected by a plastic disposable glove, the plastic bag was used to pick up the scats. The bag was then turned inside out, holding the scat inside the bag.

3.5.4. Material preparation

Each stomach/intestine sample was opened and the contents were emptied on to a sieve (mesh 1.5 mm), washed in water, and the hard parts such as feathers, fur, bones, claws, teeth and insect parts were collected. Where stomach and intestine were both present, these were opened on to the same sieve and were taken as one sample. The collected remains were then placed on petri dishes and put in the oven at 70° C for 24 hours. They were then put in small paper envelops, awaiting identification.

Scats were placed in paper envelopes and dried in an oven at 70° C for 48 hours, to free them of any viable parasite eggs. When scat preparation could not be done immediately, scats were stored in the freezer for later processing.

The dried scats were soaked overnight in warm soapy water. This helped to loosen the food mass in the scat, making washing easier. The soaked scat material was then poured onto a sieve and washed under warm water, prodding the material with a glass rod, while taking care not to macerate it. The collected remains were then treated in the same way as those collected from stomach samples.

3.5.5. Identification

Fur samples collected were identified to species by the method of Coman and Brunner (1971), and Brunner and Coman (1974). A cross section of the guard hairs in each fur sample was obtained by sectioning as described by Coman and Brunner (1971) and observed under a microscope for identification. This was then compared to reference material.

Birds were identified from feathers and claws but were not identified to species. Insects were identified from mainly the head capsule as in most cases, it was intact, making identification to genus or species easy. Where the head was absent, insects were identified from legs and wing venations. Household food scraps were identified from remains such as tomato seeds, egg shells, paper, aluminium foil, plastics, and string. Plant material was identified from leaves, grass, and small sticks.

Contents of stomach and intestine samples were more complete and easier to identify than those from scat samples, probably due to the difference between the length of digestion involved. In the case of insects, a whole insect sometimes was found in the stomach contents and after digestion, most parts were still complete. The fur found in stomach and intestine contents was much easier to identify than that from scats. The hairs in the scat samples were usually more entangled and in small pieces.

3.6. Sampling for seasonal prey abundance

From late January 1994 to mid May 1994, sampling for prey abundance around the ANU and OPH was carried out. This survey was aimed at determining whether prey intake by cats increased with increased prey abundance.

3.6.1. Insect abundance

Twenty five pitfall traps were set at each site near the base of street lights and in areas with low grass around the ANU and OPH. A small amount of 1% Phenoxy ethanol was added to the trap to preserve the trapped insects. Traps were set once a week and left in the field for two days. To ensure that insects dropped into the traps, a small hole was dug in the ground where the trap was placed, and the top of the trap was made level with the ground. Twenty five traps were set at each site. The traps were checked every two days, the trapped insects collected into other containers, and the traps were set again. The trapped insects were taken to the laboratory and identified to species. Pitfall traps were 7.5 cm diameter plastic cups set in the ground. No drift fence was used.

3.6.2. Mammal abundance

Twenty five Elliott traps were set once a week and left in the field overnight at each site around the ANU and OPH to determine the abundance of rats and mice. The trapped animals were then taken to the lab., identified and later released in the field at the spot where they were caught. The animals were identified to species.

Spotlighting around the ANU and OPH was carried out once a week, to determine the abundance of possums and rabbits. Tall trees were thoroughly checked for possums.

3.7. Data analysis

3.7.1. Analysis for diet data

The data for the diet of cats were compositional, hence the results were expressed as presence or absence of a given food item. Statistical analysis of the results was done only for the important groups of food, that is mammals, insects, birds, and scraps. Mammals that comprised the prey items were mainly rodents, Rabbit, possums, Red Fox, and Greater Glider. The statistical method used for analysis was logit modelling.

The results were categorical. That is, either a prey item is absent or present. Since preliminary analysis suggested that calculation of the probability of the occurrence of a prey item was the best way to analyse the binary result anticipated (Cunningham, statistical advisor to the graduate school. pers. comm. 1994), it was decided that application of the logit model was the most appropriate method of analysis.

The use of logit modelling gives a probability of occurrence of between 0 and 1. The probability of the occurrence of a prey item is given by

$$P_i = \frac{e}{1+e} \qquad (1)$$

Applying the logit transformation to equation 1 gives a linearised regression form as follows;

$$\text{Logit } (P_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_\kappa X_\kappa . \qquad (2)$$

where X_1 and X_2 are the variates up to κ, and β_0, β_1 and β_2 are estimated parameters (coefficients) up to κ (Collet 1991).

3.7.2. Analysis for movement and home range data

The computer program RANGES IV, developed by Kenward (1990) was used in the analysis of the radio-tracking data. The program analyses data, displays outputs simultaneously for many animals, and then uses these outputs for further study of range structure and sociality. Outputs from the main analyses were used to work out an overlap matrix of range outlines. This was useful in studying territoriality and other aspects of social behaviour. Since it was necessary to split files into different seasons, to move ranges from one file to another, RANGES IV provided the appropriate merging and splitting facilities.

CHAPTER 4. DIET STUDY RESULTS

4.1. Introduction

The data for the diet study posed a number of problems for statistical analysis. A single sample usually contained more than one prey species, and was therefore counted more than once. This resulted in the total percentage occurrence of separate prey items adding up to more than 100%, making analysis based on percentage occurrence confusing. The number of samples obtained from different study sites was not the same. Some of the samples obtained did not contain any identifiable prey remains. There was also a large number of zeros present in the data. The prey items were therefore gathered into four main groups before analysis and logit modelling was applied. The main groups were mammals, insects, birds, and scraps.

The analytical results are presented in Sections 4.2 and 4.3. Section 4.2 presents data for diet based on scat content analysis. It includes data for the diet of cats in the urban areas (the Australian National University (ANU) and Old Parliament House (OPH)). Section 4.3 deals with the data for diet based on stomach and intestine content analysis. It includes the diet of cats from the fringe areas (Mugga Lane rubbish dump (ML), Googong Nature Reserve (GNR), and Murrumbidgee River Corridor (MRC)).

For logit modelling, the data for diet were analysed in binary form (ie presence and absence of prey items) and graphed as predicted probabilities of occurrence. The confidence intervals were symmetric on a logit scale, on which modelling was carried out. However, as the graphs were drawn on a probability scale rather than the logit scale, the limits of each confidence interval were back-transformed into the probability scale, hence the asymmetry of the confidence intervals.

Since samples obtained from the fringe areas were few, and were not collected seasonally, analysis of site by season was not possible. Results for these sites are therefore based on logit models for sites, ignoring seasons. These models, however, included all the five sites that were considered for the diet study.

4.2. Analysis based on scat contents

4.2.1. Presence of insects

Analysis for presence of insects in the scats collected showed a significant site effect (change in deviance, G = 83.97; df = 1; $p<0.001$). The likelihood of insects occurring in the scats collected from the ANU was almost four times that of getting insects in the scats collected from OPH (Figure 2). Analysis revealed a significant seasonal effect (G = 42.819; df = 3; $p<0.001$), with a much greater chance of insects occurring in scats collected in Spring and Summer than in Winter and Autumn for the ANU site. There was also a significant site by season interaction (G = 9.9; df = 3; $p<0.02$) (Figure 3).

Overall, there was a less than 20% probability of finding insects in the diet of cats from OPH in all seasons. At the ANU however, there were marked differences in the predicted probabilities for the different seasons, with a more than 50% probability of getting insects in the diet of cats during Spring and Summer. For Autumn and Winter seasons however, there was a less than 25% probability of getting insects in the diet of cats at the ANU.

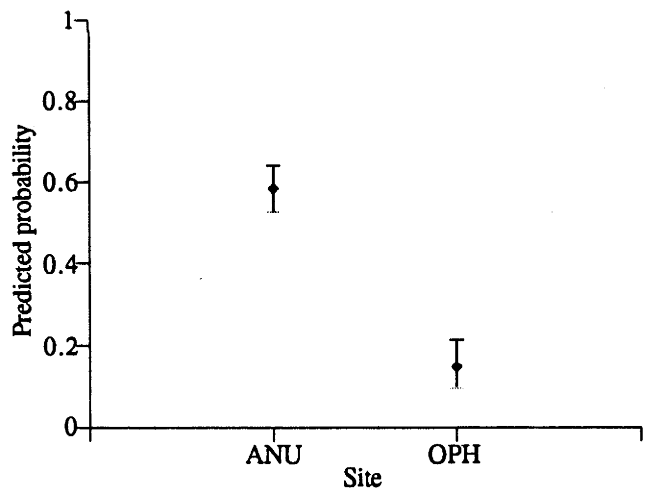

Figure 2. Predicted probability, together with 95% confidence interval, of presence of insects in scats from sites the ANU and OPH.

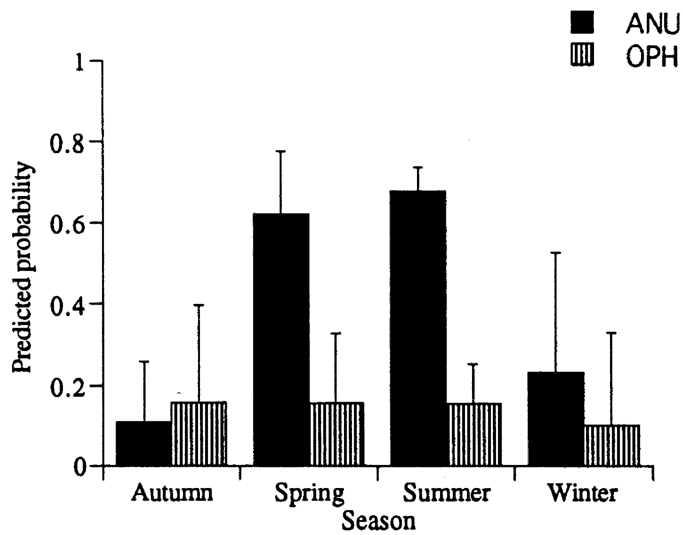

Figure 3. Predicted probability, with 95% confidence interval of presence of insects in scats from sites the ANU and OPH for four seasons

4.2.2. Presence of scraps

There was a significant site effect (G = 5.82; df = 1; p<0.02), with the probability of presence of scraps in scats from ANU one and half times that for scats from OPH (Figure 4).

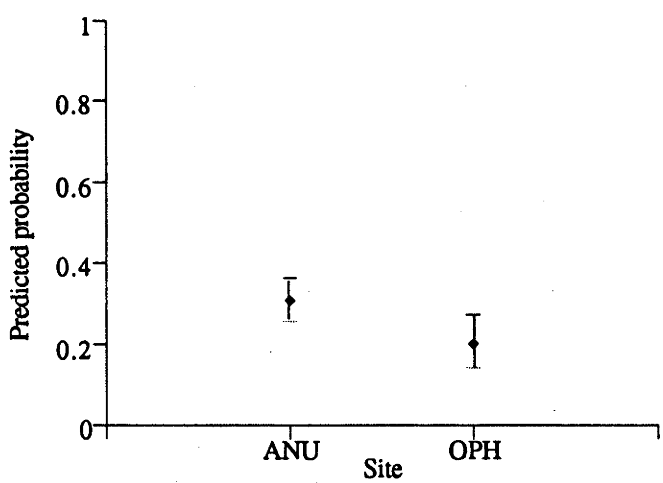

Figure 4. Predicted probability, with 95% confidence interval, of presence of scraps for sites the ANU and OPH, ignoring season.

Analysis revealed a significant seasonal effect (G = 70.32; df = 3; p<0.001), and a significant site by season interaction (G = 13.85; df = 3; p<0.01). The predicted probability of presence of scraps was high in Autumn and Winter, and lower in Summer and Spring (Figure 5). With the exception of Autumn, there was a less than 50% likelihood of cats from OPH taking scraps in all the other three seasons. From Figure 5, there appears to be no difference in the predicted probability of presence of scraps in the diet of cats from the ANU and OPH during Autumn, Winter and Spring. However, in Summer, cats from the ANU were more likely to consume scraps than those from OPH.

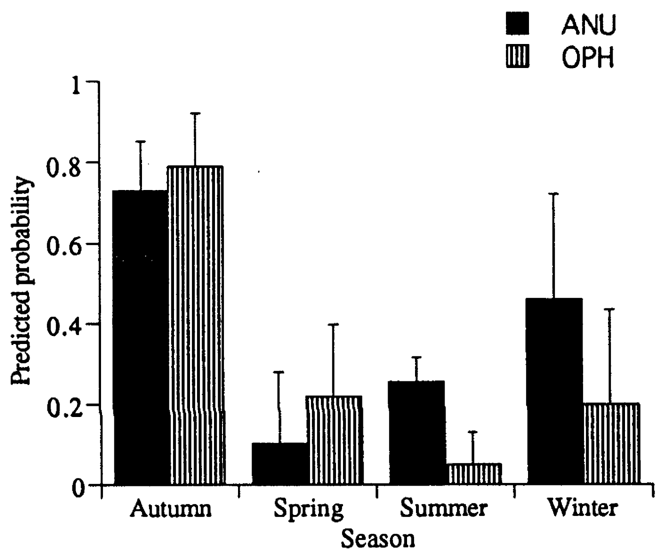

Figure 5. Predicted probability, with 95% confidence interval of presence of scraps in scats in different seasons for sites at the ANU and OPH

4.2.3. Presence of mammals

Analysis for presence of mammals in scats collected revealed no site effect (G = 0.79; df = 1; p<0.5), but there was a significant seasonal effect (G = 21.766; df = 3; p<0.001) (Figure 6). For both sites OPH and the ANU, there were marked differences in presence of mammals between seasons, Autumn - Winter seasons having lower probabilities than for Spring - Summer seasons. Predicted probability showed that there was a higher chance of cats at both sites taking mammals in Spring and Summer than in Autumn and Winter.

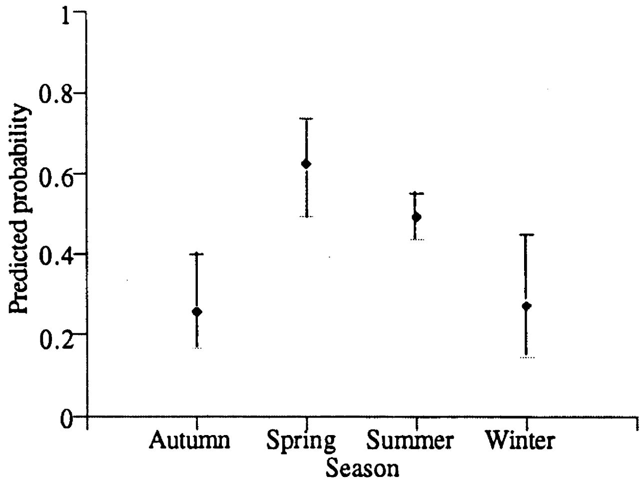

Figure 6. Predicted probability, with 95% confidence interval, of presence of mammals in scats for different seasons for sites the ANU and OPH.

4.2.4. Presence of birds

Significant site effects were revealed by the analysis for the presence of birds in the scats (G = 8.702; df = 1; p<0.01) (Figure 7). However, seasonal effects were not significant (G = 0.883; df = 3; p<0.9). Irrespective of season, there was a less that 20% probability of finding birds in scats collected at either site. Therefore, birds did not appear to be an important component in the diet of cats from the ANU and OPH.

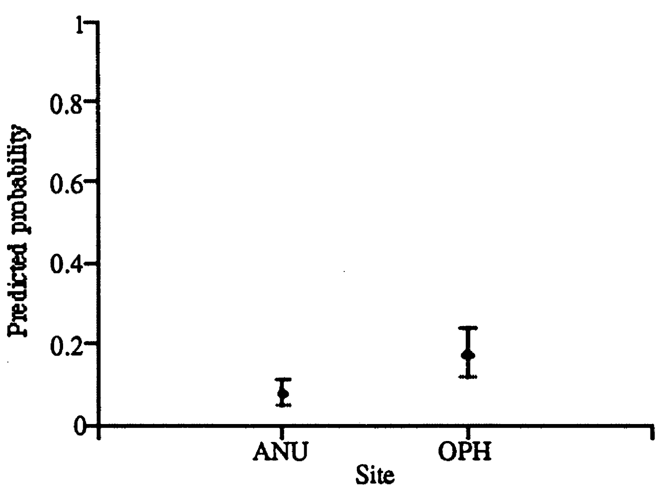

Figure 7. Predicted probability, with 95% confidence interval, of presence of birds in scats from sites the ANU and OPH, ignoring seasons.

4.2.5. Predicted prey presence in the diet of cats at the Australian National University

Comparisons based on seasonal predicted probabilities showed that in the cold seasons (Autumn and Winter), cats at the ANU will take mainly scraps for their food, followed by mammals then insects. In the warmer seasons (Spring and Summer) however, the intake of food will shift from scraps to insects and mammals. The intake of birds is likely to be low in the diet of cats at the ANU in all seasons, with a less than 10% predicted probability of their presence in the scats collected (Figure 8).

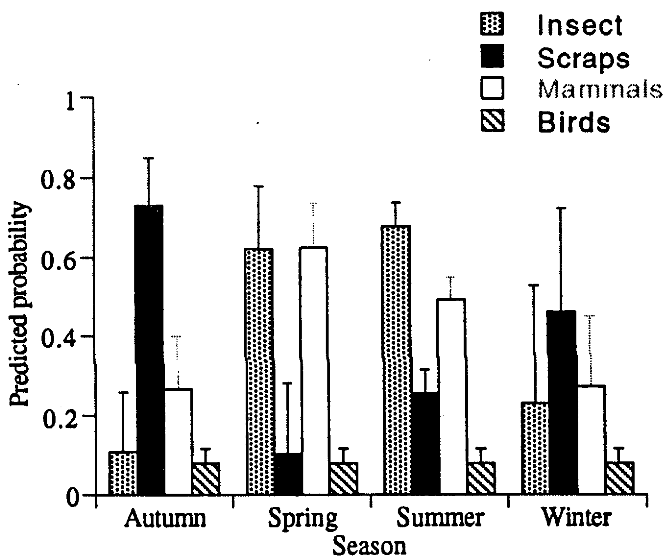

Figure 8. Predicted probability, with 95% confidence interval, of presence of groups of prey items in scats from the ANU for different seasons.

4.2.6. Predicted prey presence in the diet of cats at Old Parliament House (OPH)

Comparisons based on seasonal predicted probabilities showed a different picture of the diet of cats at OPH from those at ANU. Intake of type of prey for cats at OPH varied more dramatically from season to season (Figure 9).

In the warmer seasons (Spring and Summer), mammals were the main prey item, with the predicted probability of their presence almost twice that for each of the other prey items. Predicted probability was not much different for the presence of insects, scraps and birds (overlap of confidence intervals).

The predicted probability of occurrence of scraps in the diet of cats for the Autumn season was almost four times that for each of the other three seasons, but almost two and a half times that for each of the other prey items taken during Autumn season. However, there was no difference in the predicted probability for the presence of the other prey items (insects, mammals and birds) in the diet of cats.

The predicted probability for the presence of insects in the diet of cats for the Winter season was five times that for each of the other seasons, whose probability was each less than 20%, and four times that for each of the other prey items in the diet of cats during Winter season. However, there was no difference in the predicted probability of presence of scraps, mammals and birds.

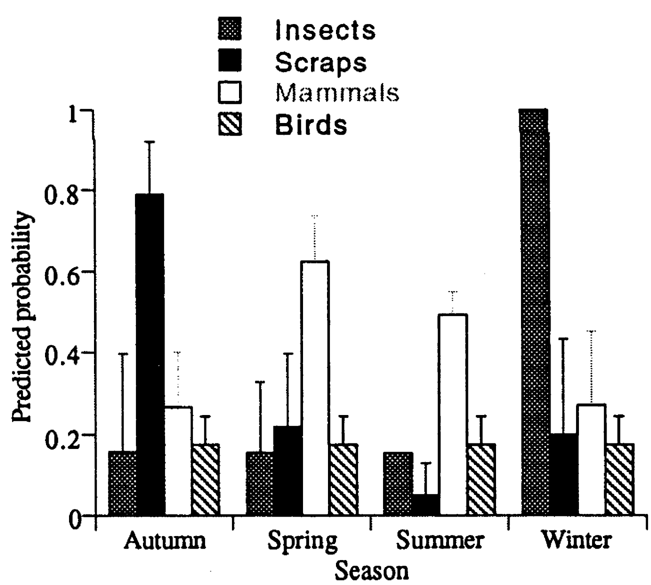

Figure 9. Predicted probability with 95% confidence interval of presence of groups of prey items in scats from OPH for different seasons

4.3. Analysis based on stomach contents

4.3.1. Presence of insects

Although the overlap of the confidence intervals would suggest that there was no difference between the three sites (Figure 10), in fact, suitable statistical testing (logit modelling) revealed that there was a significant site effect ($G = 87.152$; $df = 4$; $p<0.001$). There was almost an equal chance of getting insects in the diet of cats from ML and MRC. However, the probability of the presence of insects in the diet of cats from GNR was almost twice that for cats from ML and MRC.

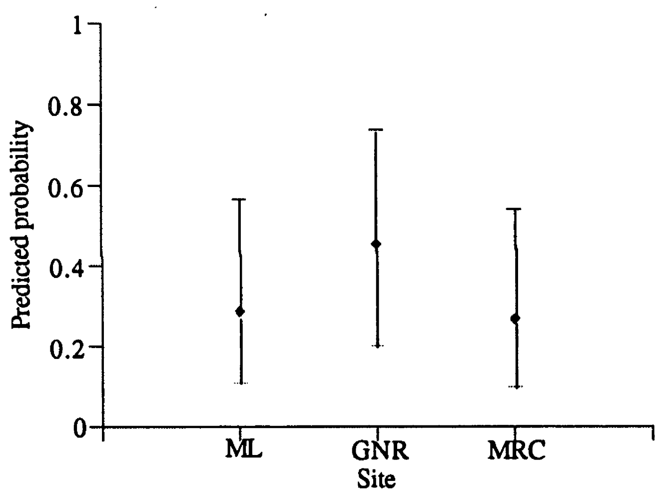

Figure 10. Predicted probability, with 95% confidence interval, of presence of insects in stomach contents.

4.3.2. Presence of scraps

Analysis showed a significant site effect (G = 43.35; df = 4; $p<0.001$). There was a more than 80% probability of getting scraps in the diet of cats at ML (Figure 11). However, for cats from both GNR and MRC, there was no likelihood of getting scraps in the diet of cats.

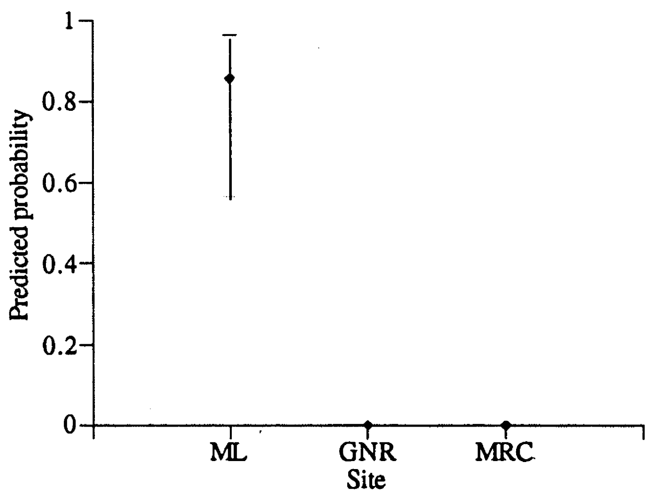

Figure 11. Predicted probability, with 95% confidence interval, of presence of scraps in stomach contents for cats at three sites.

4.3.3. Presence of Mammals

Analysis revealed no significant site effect (G = 4.751; df = 4; $p<0.5$), hence an equal chance of getting mammals in the diet of cats irrespective of the site in which they resided.

4.3.4. Presence of birds

Significant site effects were revealed by analysis for the presence of birds in the stomach contents (G = 38.753; df = 4; $p<0.001$). It was very unlikely to get birds in the diet of cats from ML, whereas for the cats from the MRC and GNR, there was more than 50% chance of getting birds in the diet (Figure 12).

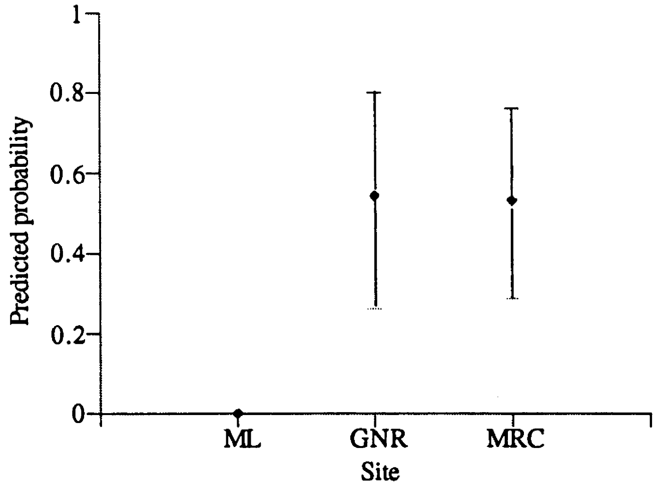

Figure 12. Predicted probability, with 95% confidence interval, of presence of birds in stomach contents for cats at three sites.

4.3.5. Predicted prey presence for each site

The probability of getting scraps was twice that of getting insects in the diet of cats from ML (Figure 13). However, it was highly unlikely that cats at ML would eat birds. For sites GNR and MRC, cats ate more birds than insects. In these areas however, there was no likelihood of cats eating scraps (Figure 14 & 15).

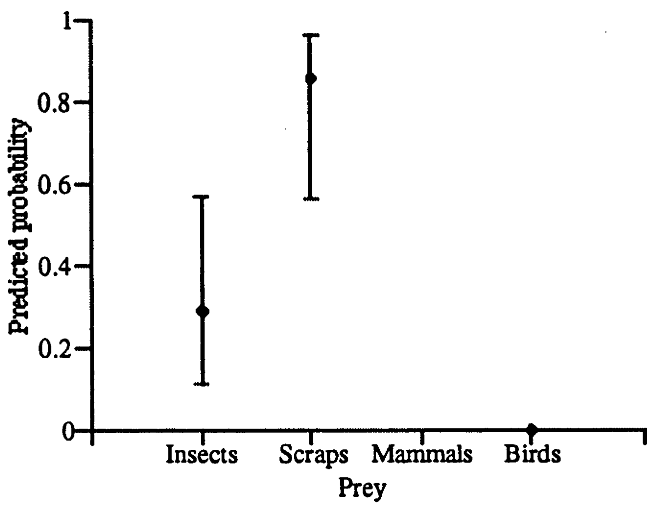

Figure 13. Predicted probability, with 95% confidence interval, of presence of prey items in stomach samples from Mugga Lane rubbish tip (ML).

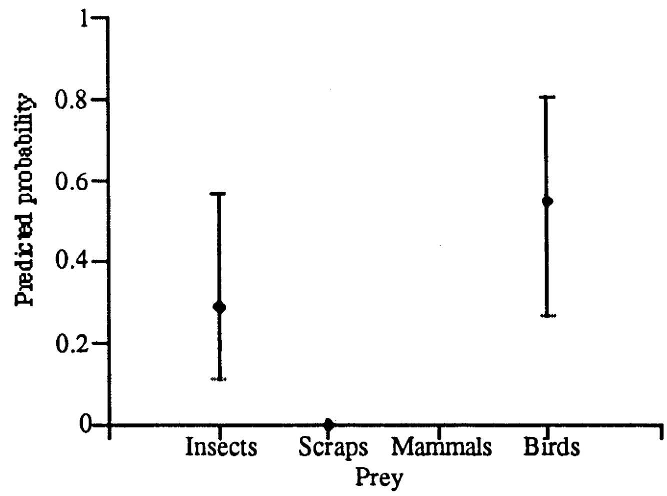

Figure 14. Predicted probability, with 95% confidence interval, of presence of prey items in stomach samples from Googong Nature Reserve (GNR).

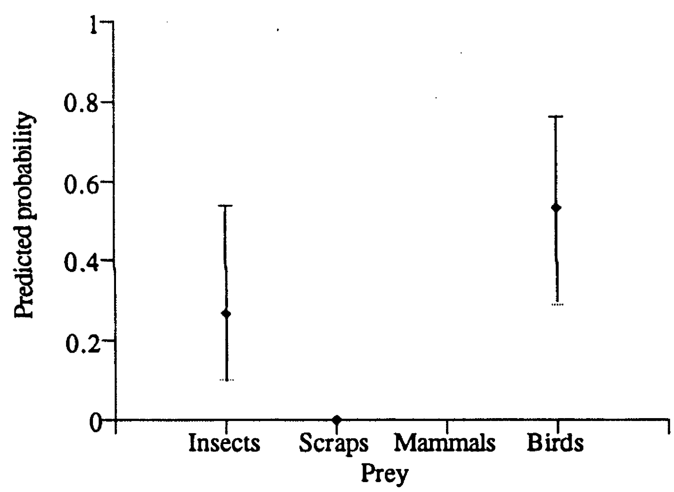

Figure 15. Predicted probability, with 95% confidence interval, of presence of prey items in stomach samples from Murrumbidgee River Corridor (MRC).

The large confidence intervals for all three sites may be due to the small sample size used for each site. Utilisation of mammals for prey at each site could not be predicted as there was no site effect, hence no site differences. From the raw data, however, it appeared likely that cats from the MRC and GNR consumed mammals rather than scraps. This might be expected simply in terms of availability.

At all the three sites, there was a less than 50% probability of insects occurring in the diet of cats. Unlike urban areas, there was a more than 50% predicted probability of birds occurring in the diet of cats from the MRC and GNR, indicating that birds form a significant part of the diet of cats at these sites. Although there was no likelihood of getting scraps in the diet of cats from MRC and GNR, there was a more than 80% predicted probalility of getting scraps in the diet of cats from ML, indicating a high dependence on scraps by the cats foraging on the dump.

4.4. Prey abundance for the cats at the urban sites (The ANU and OPH)

4.4.1. Abundance at the ANU

Possum abundance in Summer was twice that in Autumn. However, Rabbit abundance in Autumn was almost twice that in Summer. In both Summer and Autumn, possums were more abundant than rabbits. Rodents had the least average abundance, with none in Autumn (Figure 16).

Insects, particularly beetles, were more abundant in Summer, reducing greatly in Autumn. Furthermore, there was a change in abundance of beetle species in different seasons, Christmas beetles being abundant in summer, while *Aphodius* beetles were abundant in Autumn. Other insects trapped included ants, crickets, moths and flies (Table 1).

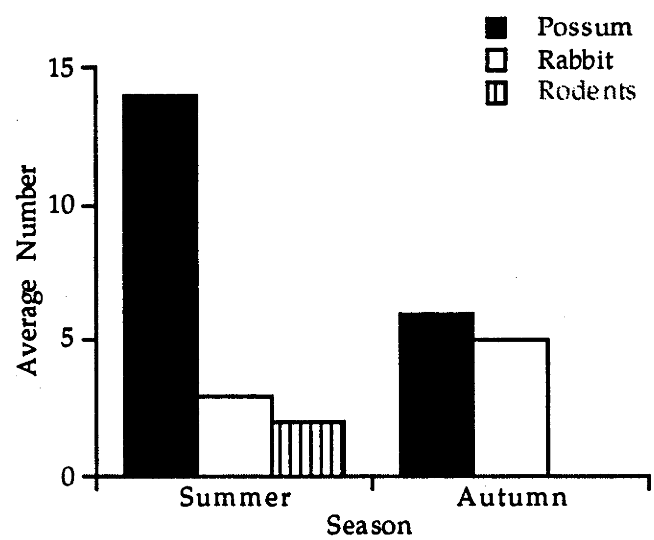

Figure 16. Seasonal abundance of mammal prey for cats at the ANU (Total number of animals).

4.4.2. Abundance at OPH

At OPH, insects were less abundant than at the ANU both in terms of numbers trapped and species (Table 1). Beetles were abundant in Summer, reducing greatly in Autumn. As at the ANU, there was a change in abundance of beetle species in different seasons, Christmas beetles being abundant in summer, while *Aphodius* beetles were abundant in Autumn. Other insects trapped included ants and moths.

Site	Season	Christmas Beetle	Aphodius Beetle	Crickets	Ants	Moths	Flies
ANU	Summer	43	0	9	35	3	2
	Autumn	3	19	2	17	3	4
OPH	Summer	17	0	0	12	4	0
	Autumn	2	7	0	11	0	0

Table 1. Seasonal abundance of insect species at the ANU and OPH sites. Note that numbers represent total numbers caught in Pitfall traps.

Possum abundance in Summer was one and a half times that in Autumn. Similarly, rodent abundance in Summer was almost one and a half times that in Autumn. However, Rabbit was more abundant in Autumn than in Summer, with the average abundance in Autumn three times that in Summer (Figure 17).

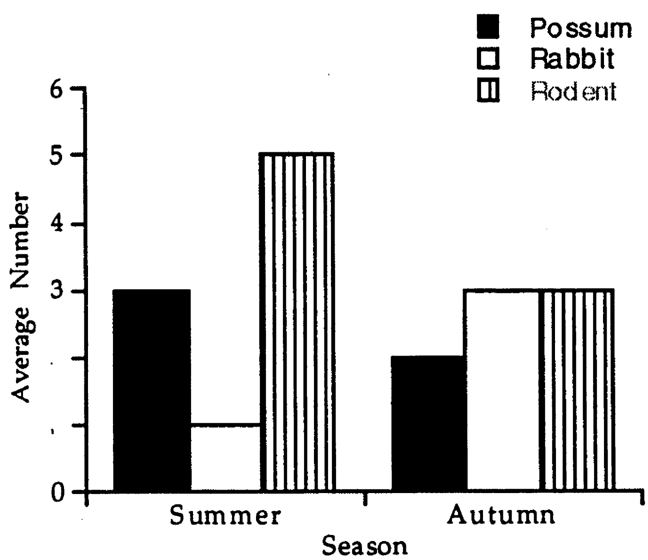

Figure 17. Seasonal abundance of mammal prey for cats at OPH (Total number of animals).

CHAPTER 5. DIET RESULTS DISCUSSION

5.1. Introduction

The decision as to whether cats in the Australian Capital Territory (ACT) are having a significant impact on the wildlife, hence warranting control measures, can best be reached through proper understanding of the feeding and movement activities of these cats, as well as the likelihood of their disease transmission to other wildlife. Definite determination of the feeding habits of the cats in the ACT can best be obtained by finding out the actual prey items that such cats are taking and in what proportions they are taking them.

Examination of the raw data showed apparent differences in prey eaten, but the data were inadequate for statistical testing to determine the significance of differences in prey species taken or to test for seasonal differences. In general, the main prey groups occurred in the diet in proportions that might be predicted from their likely availability at each site and in each season. However, for more precise determination of possible differences between the diet of cats in the urban and fringe areas, more sampling of the diet of fringe cats is required, over a number of seasons.

5.2. Scat content results

5.2.1. Insects

Cats at the ANU ate a wider variety of insect species (11) compared to those at OPH (7) (appendices 3 and 4). At both sites, the ANU and OPH, cats took moths, beetles, ants, flies, cockroaches, grasshoppers and butterflies. However, at the ANU, cats also took spiders, bees and cicadas. Cats at OPH took only christmas beetles while those at the ANU took mainly christmas beetles, but also *Aphodius* beetles. Many of the insect species taken at both sites tend to congregate around street lights. As the ANU is better lit than OPH, more may drop to the ground to be taken by cats at the ANU than at OPH. During the radio-tracking sessions in seasons when beetles were abundant, it was observed that the beetles concentrated mainly around the base of a street light.

The occurrence of insect species in the diet of cats varied from season to season and was different for different insect species. This difference in the occurrence of insect species may be due to differences in the abundance of the species at the given time and place. Significant differences in the presence of insects in the contents of scats from the ANU and OPH indicates that cats at the ANU will take insects more than cats from OPH.

Considering the seasonal variability in the occurrence of insects in the diet of cats from the ANU and OPH, though there was not much seasonal variability for the cats at OPH, analysis showed that the presence of insects in the diet of cats at the ANU in Spring and Summer was likely to be twice that for the Autumn and Winter seasons. The prey abundance survey showed that at the ANU insects, especially beetles, were more abundant in Summer, reducing in Autumn. This indicates opportunistic feeding, cats at the ANU taking more insects in the season when they are more abundant.

5.2.2. Scraps

Results revealed a greater likelihood of cats at the ANU taking scraps than those at OPH. This may be due to the higher presence of scraps at the ANU than at OPH, reflecting a higher concentration of garbage bins and public eating places and greater abundance of scraps from which the cats can scavenge at the ANU. During radio-tracking, cats were seen, on most occasions, to concentrate around garbage bins and eating places at the ANU.

At both sites, there was evidence of cats being fed by people. At times, containers of food and milk were found full or being filled by persons at both sites and cats were seen eating such handouts. At both sites, cats were fed, or food was put out at particular places, and at a certain time. The cats soon learnt where and when they were fed, gathering at the appropriate place and time every day.

Since there was an abundance of scraps and food handouts for the urban cats, the contribution of the scraps to the diet of cats in the urban areas would be expected to be high, since these cats seem to be opportunist feeders. Nevertheless, ignoring seasonal differences, there was a less than 50% predicted probability of the presence of scraps in the diet of cats from both sites, indicating that overall, scraps were not a major portion of the diet of cats. However, food scraps and food handouts like milk and cat food are very soft and easily digested, leaving very little or no identifiable remains. Therefore, the results obtained were likely to have underestimated the presence, hence the importance of scraps in the diet of cats.

Clearly, the observations of cats being fed by humans and the presence of scraps in the diet of cats from both the ANU and OPH indicate that such cats are not truly feral, but commensal.

Seasonal variability in the presence of scraps in the diet of cats showed that there was a high likelihood of scraps occurring in the diet of cats at both sites during the cold seasons (Autumn and Winter) and a lower likelihood during the warm seasons (Spring and Summer). This may be due to reduced availability of most of the other prey at such times, hence, as was suggested by previous studies (Newsome 1991; Tabor 1981), the cats becoming increasingly commensal. Furthermore, most of the Summer season falls within the vacation period of the ANU academic program. It would therefore be expected that abundance of scraps at the ANU would be reduced. However, the predicted probability of the scraps occurring in the diet of cats at the ANU for the Summer season was higher than for Spring. If there are fewer scraps available in Summer, this indicates preferential rather than opportunistic feeding.

Predicted probability showed a higher likelihood of the presence of scraps in the diet of cats from OPH in Autumn compared to other seasons, with the Summer season having the lowest likelihood. This may be due to the reduced abundance of prey in Autumn, hence a shift to scraps and food handouts.

5.2.3. Mammals

Cats at the ANU ate more mammal species than cats at OPH (appendices 3 and 4). At both sites, cats took rodents, rabbits and possums. However, cats at the ANU also ate gliders, kangaroos and foxes, but all these had single occurrences. Unless they were very young, hence likely to be killed by cats, the kangaroo and fox might have been carrion from road kills. The glider may have been taken by a cat that could have visited the neighbouring urban-bush interface (Black Mountain).

The high predicted likelihood of presence of mammals in Spring and Summer may be coincidental (Fitzgerald and Karl 1979). It is during these seasons that most breeding activities of mammals like rabbits, rodents, and possums take place. Therefore, in Spring and Summer, it is highly likely that mammals like rabbits will be preyed upon heavily, as young ones are abundant (Fitzgerald and Karl 1979; Liberg 1984) and are inexperienced and vulnerable.

In Spring, young possums are likely to begin fending for themselves and may be particularly vulnerable to predation (Fitzgerald and Karl 1979). Furthermore, increased occurrence of possums in the diet of cats in this study occurred at the time when the possums are expected to be breeding. Since most of the Summer season falls within the vacation period of the ANU academic program, there is reduced abundance of scraps. This might result in a switch from scraps to mammals such as possums in the diet of cats at the ANU in Spring and Summer.

Though possums may be arboreal and normally out of reach of cats, they were eaten by cats in this study. The reason for this may be that Ring-tail Possums (*Pseudocheirus peregrinus*) frequent the ground when feeding, and may then be more vulnerable to cats (Triggs *et al.* 1984).

Abundance of rodents may increase in Spring and Summer due to their increased breeding activities. This may make them more vulnerable to the Cat in its role as an opportunist predator.

5.2.4. Birds

Predictions based on results for scat samples for cats from OPH and the ANU agree with the findings of Coman and Brunner (1972) and Fitzgerald and Karl (1979), that birds are a minor item in the diet of cats. This may be due to greater availability of other alternative prey, and the difficulty of capturing birds. It could also be that the birds taken are those caught where they had difficulty escaping, or were caught during a lapse in attention to what was going on around them.

5.2.5. Diet of cats at the ANU and OPH

Results show that cats at the ANU and OPH are not truly feral but commensal, taking scraps and food handouts during the colder seasons (Autumn and Winter).

The portrayed commensalism points to opportunistic feeding behaviour, for it is during such seasons that reduced abundance of vulnerable mammal prey prevails.

At the ANU, prey intake appears to vary from season to season depending on the abundance and availability of the vulnerable age groups of a given prey item. When it is much warmer (Summer and Spring), the young and more vulnerable mammals and also insects become increasingly abundant. Cats are therefore likely to increase mammal intake. As the abundance of insects and mammals reduces in Autumn and Winter, cats are likely to become increasingly commensal, feeding from the garbage bins and public eating places, and also depending on food handouts from people.

At OPH, however, insects occur frequently in the diet in Winter, though they are likely to be of low abundance in this season. This may indicate that at such times, cats are not behaving as opportunists, but rather, as preferential feeders. As for cats at the ANU, in Autumn, due to reduced abundance of mammals and insects, cats at OPH will become increasingly commensal, eating from garbage bins and public eating places, and also taking much of the food handouts left by people. In Spring and Summer, as mammals become increasingly abundant, as opportunist feeders, the cats at OPH will shift intake from insects and scraps to mammals.

Generally therefore, cats in the urban areas appear to be mainly opportunist feeders, taking prey that is most abundant at a given time. However, on some occasions, these cats appear to exhibit preferential feeding habits. At both sites, birds are of low occurrence in the diet.

5.3. Stomach content results

Due to the small sample sizes from cats in the fringe areas, the resulting large confidence intervals for the predicted probabilities for the prey items in the diet of cats from the fringe areas made valid deductions and interpretation of possibilities difficult.

5.3.1. Insects

Results showed significant site differences in the occurrence of insects in the diet of cats at the three sites. Cats at Googong Nature Reserve (GNR) took more insect species than those at either Mugga Lane dump site (ML) or Murrumbidgee River Corridor (MRC) (Appendices 5, 6 and 7). Of the identified insects, cats at GNR took gryllids, mantids, moths and grasshoppers. However, cats at ML took only beetles, while those at MRC took gryllids and dragonflies. This might have resulted in the predicted probability differences reported. Furthermore, seasonal effects were not accounted for. Therefore, these differences may have been due to season of collection rather than a site effect.

5.3.2. Scraps

Considerable site differences in the presence of scraps in the diet of cats at the three sites were revealed by the results. As MRC and GNR are fringe areas with very few garbage bins, only a few rarely used eating places, and far away from people handing out food to the cats, there should be a low availability of scraps for cats to feed on. Any scraps present in the diet of these cats would be from food leftovers around picnic sites in these areas. The lack of scraps in the diet of cats at MRC and GNR indicates that such cats are truly feral, and must hunt for themselves to obtain food.

At ML however, the abundance of household food scraps in the garbage dumps provides easy food for the cats, and this is likely to attract a big population of cats to the dump site. It is not suprising that there was over 80% predicted probability of the presence of scraps in the diet of cats at this site.

5.3.3. Mammals

Cats at MRC ate rabbits, possums and kangaroos. Mammals taken by cats at GNR consisted of rodents and rabbits, while cats at ML ate rabbits, rodents and possums (Appendices 5, 6 and 7). As the differences in the species and proportions of mammals taken at the three sites were not statistically significant, additional stomach sampling is required to permit more sensitive testing.

5.3.4. Birds

Contrary to reports in some previous studies that birds are a minor item in the diet of cats (Coman and Brunner 1972; Fitzgerald and Karl 1979), birds were an important item in the diet of cats at MRC and GNR. Many of the birds however might have been nestlings that were taken as they left the nest. Since there are not many scraps and food handouts at MRC and GNR, the cats rely on hunting to meet their food requirements, and this may result in a high likelihood of birds being hunted and caught. Although there was an almost equal predicted probability of getting birds in the diet of cats at MRC and GNR, there was no predicted chance of getting birds in the diet of cats at the dump site (ML).

5.4. Diet of cats in the Australian Capital Territory

Cats in the urban areas (the ANU and OPH) took a greater variety of insect species compared to those in the fringe areas (MRC, GNR and ML). In general, urban cats mainly ate moths and beetles, while cats at MRC and GNR mainly took gryllids. The ease of capture of moths as they are attracted to the street lights in the urban areas, which may not be the case at MRC and GNR, may have resulted in differences in the moth intake at these sites. This may be due to the urban areas being well lit compared to the fringe areas.

Cats in the urban areas showed signs of commensalism, as food scraps occurred in their diet. However, the scraps made only a minor contribution to the diet and were eaten only in certain seasons. With the exception of the cats at ML, no scraps were taken by cats at MRC and GNR, indicating that such cats are truly feral.

Due to the high concentration of food scraps in the garbage dumped at ML, scraps made a major contribution to the diet of cats at ML. However, although the presence of scraps in the diet has been used as an indicator of commensalism (hence non-feralism), cats at ML may be truly feral, taking scraps only because they are in high concentration at the site.

Cats in the urban areas took more mammal species than those in the fringe areas. This may be due to the differences in sample size and the length of time over which the samples were obtained. However, as differences in the species and proportions of mammals taken in different sites were not statistically significant, more sampling is needed to permit sensitive testing of differences between sites and between mammal species taken.

Cats in the fringe areas took birds more than those in the urban areas. Birds formed a significant part of the diet of cats in the fringe areas, while in urban areas, birds made only a minor contribution to the diet of cats.

Cats from the ANU took more carrion than those from MRC and OPH and no carrion was identified in the contents of samples from GNR and ML. The occurrence of carrion in the contents of samples from the ANU may be due to the high possibility of road kills on the neighbouring roads.

Plant material was found in the diet of cats from both the urban and the fringe environments. In the urban areas, plant material may have been taken as cats scavenged on the food leftovers around public eating places and garbage bins. They may have also been taken as the cats fed on the food handouts. Also, the method of capture may have resulted in much plant material like grass being taken by the cats, as Coman and Brunner (1972) found that trapped cats bite at the surrounding vegetation in their attempts to escape. However it is possible that in both environments, plant material like grass was taken intentionally by the cats as part of their normal diet.

Reptiles were also found in the diet of cats from the urban areas, but not for the fringe cats. However, they occurred in the diet of cats only in Spring, and made a negligible contribution.

5.5. Diet of cats based on scat and stomach content analysis

The diet of cats in the urban areas was based on scat content analysis while that for the fringe cats was based on stomach content analysis. Generally, stomach contents were easier to analyse than the scat contents. Scat contents, especially the hairs, were more entangled and digested to small bits, making analysis quite difficult. However, the hairs in the stomach contents were almost of complete length, less entangled, and appeared as a tuft of hair pulled off the skin. Sometimes, the hairs were still attached to the skin, making selection of hairs for a crossection preparation easier. Similarly, insect parts were more complete in the stomach contents than in the scat contents. This may be due to the level of digestion involved. The scat contents go through a longer digestion process than the stomach contents hence the more likelihood of the scat contents being digested to smaller pieces than stomach contents. Furthermore, a scat is usually a hard ball, especially if it is not fresh. As it is prodded to separate the contents during washing, the chances of macerating the contents are higher than the easier-to-wash stomach contents.

The differences in the diet of cats at the urban sites and fringe sites already reported also represent the differences in the diet of cats based on scat and stomach contents. These may have been due to site differences, sample size and seasonal differences, rather than the methods used.

CHAPTER 6. HOME RANGE, BEHAVIOUR AND ACTIVITY

6.1. Introduction

To devise better management strategies for the feral cats in the A.C.T, it is important to know which prey species are being affected by any given cat population, and the extent to which the impact is spread. The movements and home ranges for the feral cats in the urban areas were determined so as to gauge the extent of their predatory effects. This study was intended to reveal the areas of greatest attraction to these cats and the times of great activity, as these will be useful guidelines in designing control or management techniques for these cats.

A mixed model was used in statistical analysis of significant differences in gender, season, and gender by season interaction. In this model, the animal was considered a random effect, and gender and season as fixed effects. The data were unbalanced and estimation was by restricted maximum likelihood (Ross Cunningham, statistical adviser to the Graduate School, pers. comm.).

6.2. Physical characteristics

Physical characteristics of cats trapped are shown in Table 2. Adult male cats weighed more (3.89-4.2 kg) than adult females (2.9-3.3 kg). There were 4 cats with tabby coat colour and 3 cats with black. With the exception of one male cat, cats were in good condition. The minor flesh wounds might have been obtained as the cats struggled in the traps. All the female cats were pregnant at the time of trapping, but Tina disappeared before she could drop her litter. Bony and Lena however dropped litters late in December and were lactating during the last tracking season. Bony and Lena each had 3 kittens.

6.3. Activity

Observations on the activity pattern of the cats at the ANU, based on radio-tracking, revealed that cats were mainly active at night, while remaining almost inactive during the day. Cats were considered active if they were moving around or feeding. They were considered inactive if they remained stationary in one place for two consecutive hours. Activity studies revealed that cats were mainly active around early evening and night (7:00 pm to 11:00 pm) and dawn (5:00 am to 7:00 am) when they would concentrate around their normal feeding places. During the day, cats remained mainly inactive, seated or lying down in one place, venturing away only when disturbed by the noise from the signal on the radio receiver. Between 11:00 pm and 5:00 am, the activity of cats declined, the cats remaining in almost the same place. Occasionally, cats of opposite sex were seen seated next to each other during the times when they were inactive.

Female cats were mainly active during the early hours of the night (7:00 pm to 11:00 pm), but reduced their activity late in the night, and remained inactive, usually behind bushes or under buildings during the day. One male, Kat, was active almost the whole night, but remained inactive during the day. The activity pattern for Hati was similar to that for Kat. Tommy, however, maintained an activity pattern similar to that of the female cats, and was usually seen moving about with another cat.

6.4. Home range area

6.4.1. Overall range areas

Seven cats (Tommy, Tina, Hati, Kat, Bony, Lena and Bat) were fitted with radio transmitters. However, locations were obtained on only six cats (Tommy, Tina, Hati, Kat, Bony, Lena).

The data were treated in two ways by the RANGES IV program (Kenward 1990). An outer convex polygon round the fixes, illustrating the location of all the fixes was plotted (Figures 18). The home range area for each animal was estimated using the minimum convex polygon method (Kenward 1990). Table 3 presents the home range areas calculated for a sample of 3 males and 3 females from the 1993-94 season.

Records ceased on Hati when he shed his transmitter and could not be recaptured again, on Tommy when he died of unknown cause, and on Tina when she could not be traced, either due to transmitter failure or she might have died while down in a drain, thus a signal from the transmitter could not be received. Bat was probably a transient because when released after fitting a transmitter, no signals were received in subsequent searches.

Three female cats that were radio-located had home ranges varying from 13.15 to 42.68 ha (mean = 24.95 ha, SD = 15.63). A sample of 3 male cats had home ranges varying from 12.67 to 34.35 ha (mean =24.21 ha, SD = 10.91) (Table 3). Considering the standard deviation (SD), females had a higher SD, indicating that their areas were more widely spread than those of males. However, this might be due to the range area for Bony being more than twice the area of each of the other two females. For example, if the area for Bony is excluded, the mean comes down to 16.08 ha and SD = 4.14. Analysis showed no significant differences between the home range areas for males and females (p=0.533).

ID	Sex	Age	Weight (kg)	Head and body length (cm)	Tail length (cm)	Coat colour
Hati	male	adult	4.12	47.5	25	black
Tommy	male	juvenile	1.45	33.5	21	black
Bat	male	adult	4.2	50.2	28.5	tabby
Kat	male	adult	3.89	47	27.5	tabby
Tina	female	adult	3.3	48	26	fine tabby
Bony	female	adult	2.9	42.5	24	black
Lena	female	adult	2.97	46.5	25.5	tabby

Table 2. Physical characteristics of cats radio tracked at the ANU.

ID	No. of fixes	Area (ha)	Duration of tracking (weeks)
		(Males)	
Hati	23	25.62	11
Tommy	40	12.67	8
Kat	157	34.35	33
Mean = 24.21 ha	SD = 10.91 Range =	12.67 to 34.35 ha	
	(Females)		
Tina	52	19.01	16
Bony	179	42.68	33
Lena	171	13.15	33
Mean = 24.95 ha	SD = 15.63 Range =	13.15 to 42.68 ha	

Table 3. Radio-tracking data and estimated area of range for six cats at the ANU.

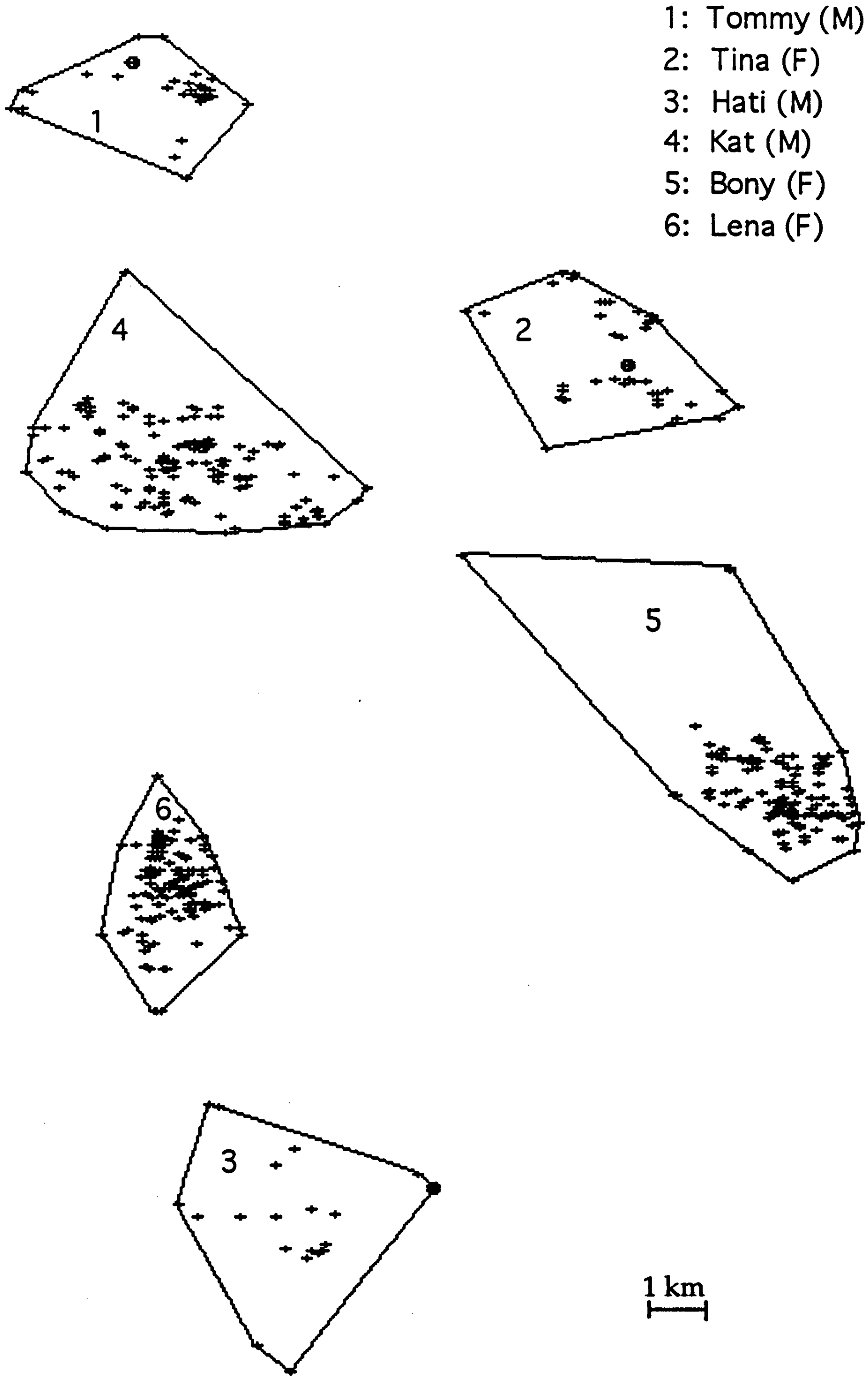

Figure 18. Convex polygons around the locations obtained on cats radio-tracked at the ANU for all the seasons.6.4.2. Weight as the determinant of home range size

6.4.2. Weight as the determinant of home range size

With only 6 weight observations and a varying number of observations on each cat, it is not possible to relate weight to home range area, although it appears that area may increase with increasing weight. The relationship between weight and area occupied for two cats deviated from the normal trend for the other cats. Of all the cats, Bony with a weight of 2.9 kg occupied the largest home range. Furthermore, Hati weighed more than Kat, but occupied a smaller range area than Kat did (Figure 19). This may be due to the longer tracking period for which Kat was radio-tracked as compared to Hati, hence more locations obtained on Kat and thus the bigger home range area.

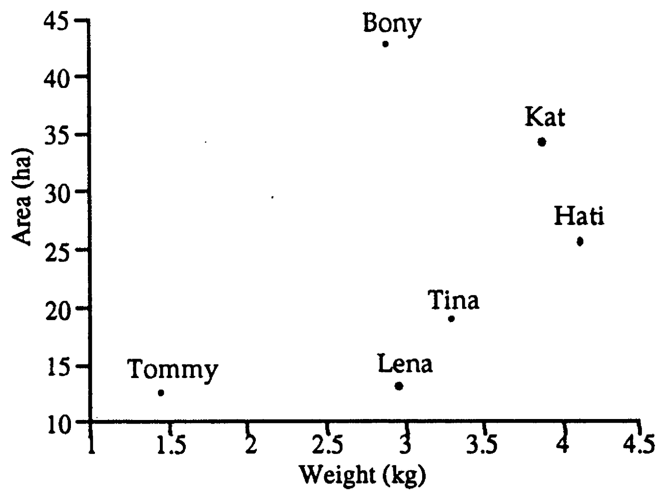

Figure 19. Relationship between home range size and body weight.

6.4.3. Number of locations (fixes) as the determinant of home range size

The determined home range area appeared to increase with increasing number of locations obtained on the animal. However, two observations deviated from this normal trend. More locations were obtained on Lena (171) than on Kat (157). However, Kat occupied a larger home range area than did Lena (Figure 20). The difference may be related to sexual differences in relation to home range area occupied by a given sex, females (eg. Lena) occupying smaller ranges than males (eg Kat). Furthermore, fewer locations (23) were obtained on Hati than on either of the other cats that were radio-tracked (> 25). However, Hati occupied a larger home range area than Tommy and Tina. The difference in the ranges occupied by Hati, Tommy and Tina may be related to age differences. Hati and Tina were adults while Tommy was a kitten, with a greater likelihood of occupying a smaller home range area than adult cats.

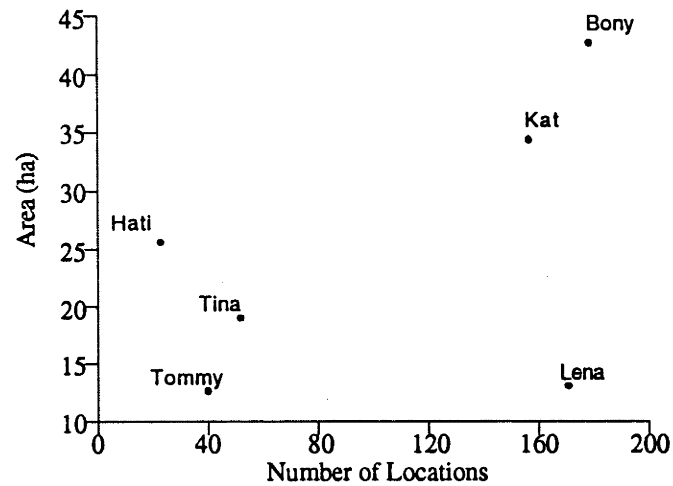

Figure 20. Relationship between home range size and number of locations.

6.4.4. Range overlap

The ranges of most of the cats overlapped with the ranges of neighbouring cats (Figure 21). There was less male-male than male-female overlap found (mean = 0.31 ha) (Figure 22). Of the three males studied, overlap of home ranges was found for cats Hati and Tommy the kitten (Table 4).

More female-female overlap was found (mean = 3.75 ha) (Figure 23). Overlap observed between females Bony and Lena was almost 9 times that observed between other female-female pairs. However, this might have been due to the longer radio-tracking time, hence more locations obtained for both Lena and Bony, compared to Tina (Table 3). Furthermore, these two female cats were radio-tracked for the same length of time and at the same times.

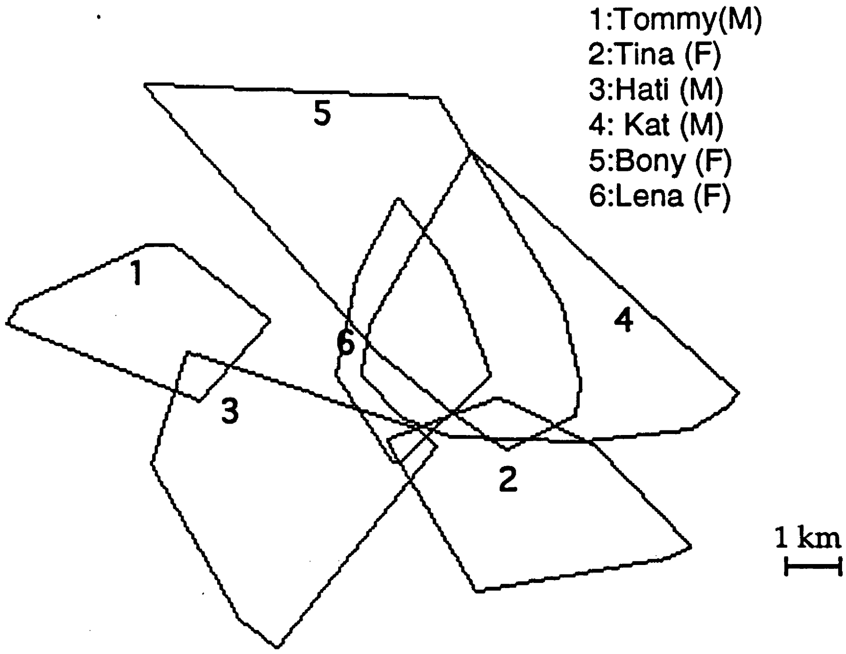

Figure 21. Plot of overlap between the ranges of cats trapped at the ANU over all seasons.

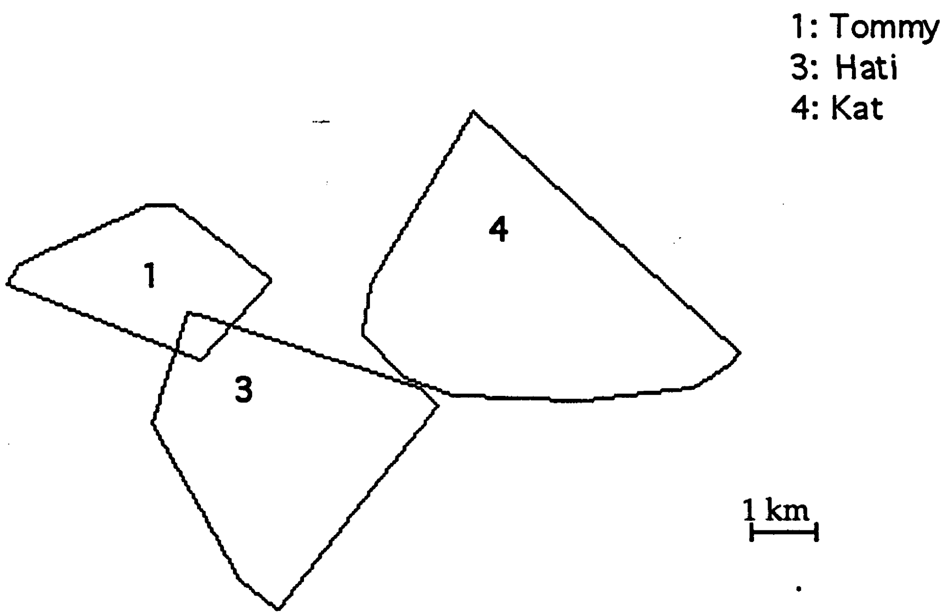

Figure 22. Plot showing overlap over all seasons between home ranges of male cats radio tracked at the ANU.

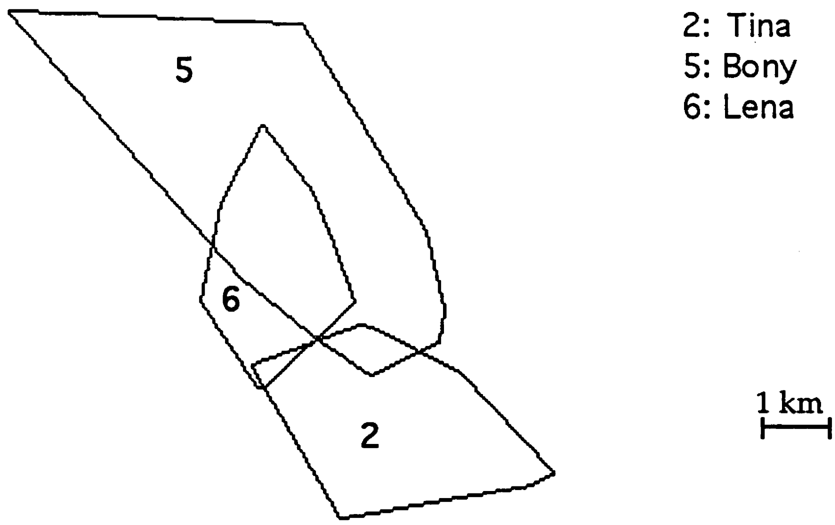

Figure 23. Plot showing overlap over all seasons between home ranges of female cats radio tracked at the ANU.

The home ranges of most of the cats overlapped, sometimes considerably, with those of at least one neighbour of opposite sex (Table 4) (mean = 3.55 ha). The home range of the male Kat overlapped considerably with those of females Bony and Lena, but considerably less with that of Tina. This may be because most of the locations on Kat were obtained after Tina had disappeared.

There was little overlap between the home ranges for Hati and Tina, and also between the home ranges for Hati and Lena. No overlap was found between the home ranges for Hati and Bony. However, both Bony and Lena were radio-tracked after Hati had shed the transmitter. No overlap was found between the home range of Tommy and that for each of the three females. This might be so because most of the locations on females Bony and Lena were obtained after Tommy had died.

Name	Range 1 (ha)	Range 2 (ha)	Overlap (ha)
Kat vs Hati	34.35	25.62	0
Hati vs Tommy	25.62	12.67	0.92
Tommy vs Kat	12.67	34.35	0
Tina vs Bony	19.01	42.68	1.53
Bony vs Lena	42.68	13.15	9.17
Lena vs Tina	13.15	19.01	0.54
Kat vs Tina	34.35	19.01	2.02
Kat vs Bony	34.35	42.68	19.78
Kat vs Lena	34.35	13.15	8.49
Hati vs Tina	25.62	19.01	0.73
Hati vs Bony	25.62	42.68	0
Hati vs Lena	25.62	13.15	0.97
Tommy vs Tina	12.67	19.01	0
Tommy vs Bony	12.67	42.68	0
Tommy vs Lena	12.67	13.15	0

Table 4. Overlap over all seasons between home ranges of the different cats at the ANU.

While male cats maintained almost exclusive home range areas, the mean overlap of female ranges was almost three times that for male-male range overlap. Similarly, with the exception of Tommy, there was overlap between the ranges for cats of the opposite sex, the mean overlap for the male-female ranges being almost equal to that for female-female, and 3 times that for male-male overlap (Figure 24, Table 4).

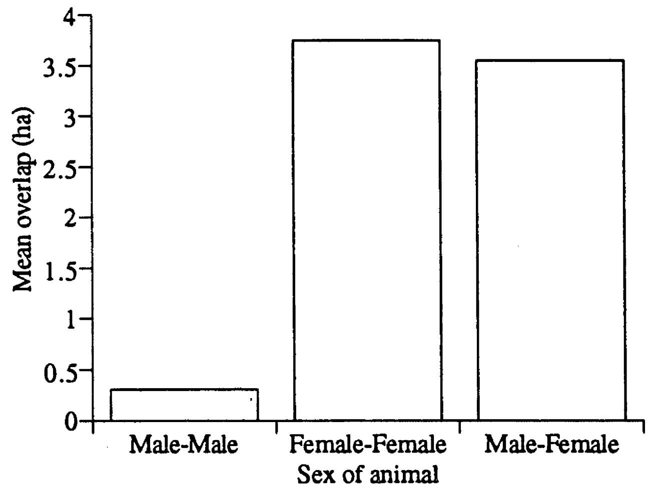

Figure 24. A plot of mean values for the overlap between the home ranges of different pairs of cats radio tracked at the ANU.

6.5. Home range use analysis based on the harmonic mean fix technique.

The ranges for the cats radio-tracked at the ANU have been expressed as an outer convex polygon drawn around all the fixes obtained on a cat. However, this polygon area reflects the presence of a few isolated outflung fixes, rather than the cat's "core range", an area where the cat spent most of its time.

Figure 25 provides, for each of the cats radio-tracked at the ANU, boundaries for core territories of peeled convex polygons based on excluding fixes furthest from the harmonic mean fix (Dixon and Chapman 1980; Spencer and Barrett 1984). Table 5 provides estimates of core areas together with a maximum area.

ID	Area (ha)			
	maximum	90%	70%	50%
1 (Tommy)	12.67	10.81	2.63	0.2
2 (Tina)	19.01	13.64	6.46	2.67
3 (Hati)	25.62	20.99	9	1.45
4 (Kat)	34.35	19.89	10.91	6.27
5 (Bony)	42.68	8.97	5.5	2.66
6 (Lena)	13.15	7.05	3.7	2.05

Table 5. Estimates of three core areas for the peeled convex polygon areas shown in Figure 33.

From Figure 25, Tommy spent half of the time in just over 1.5% of his entire home range, occupying an area of 0.2 ha. Tina spent half of her time in 14% of her entire home range, occupying an area of only 2.67 ha, while Hati spent 70% of his time in 35% of his entire home range, occupying an area of 9 ha. For 90% of the time, Kat utilised 58% of his entire home range, occupying an area of 19.89 ha. For 90% of the time, Bony utilised 21% of her entire home range, occupying an area of 8.97 ha, while Lena 90% of the time utilised 54% of her entire home range, occupying an area of 7.05 ha.

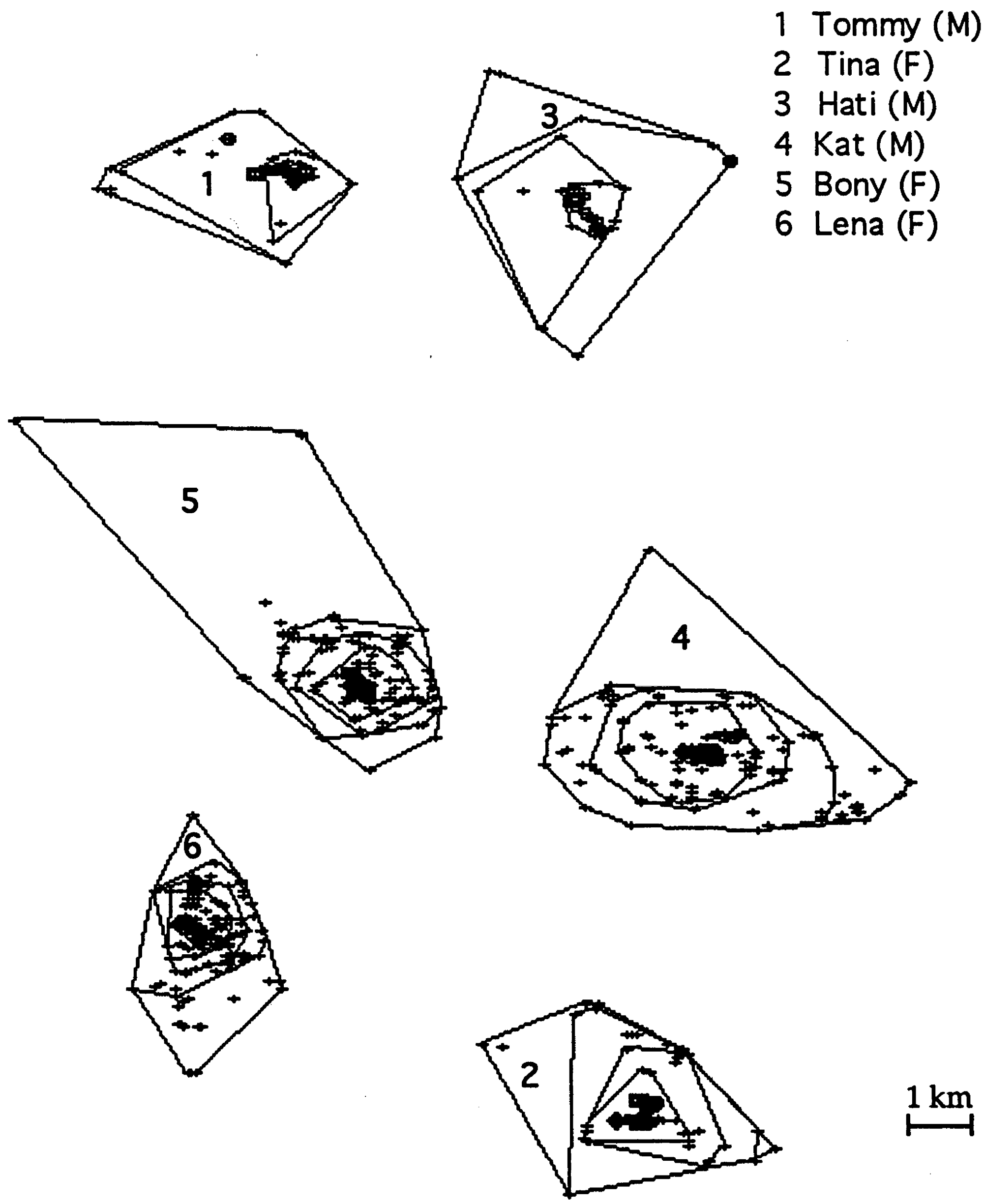

Figure 25. Plots of peeled convex polygon areas at 100%, 90%, 70% and 50% for the cats radio-tracked at the ANU for all the seasons.

6.6. Seasonal home range

6.6.1. Size

Seasonal variations in the home range area for Hati, Tommy, and Tina were obtained for only two seasons, Winter and Spring. Locations on Kat, Bony, and Lena were obtained in three seasons, Spring, Summer and Autumn.

Statistical analysis showed no significant differences in the home range areas for the cats, for the different seasons ($p=0.382$). Also, interaction between gender and season was not significant ($p=0.145$). As indicated below for several of the cats, the raw data indicated considerable differences between seasons, but clearly, the variability in the data available were inadequate to show statistically that these differences were real.

One male, Kat, that was tracked for three consecutive seasons (Spring, Summer and Autumn), had home range areas ranging from 11.54 to 34.3 ha. Its home range area in Summer was three times larger than that for Spring and two and half times larger than that in Autumn.

One female cat, Bony, tracked for the same period as Kat, occupied the largest home range area in Autumn. Her range area in Autumn was almost four times that in Summer and four and half that in Spring. However, one of the females, Lena, tracked for the same period of time as Kat and Bony, maintained almost the same home range area in the three seasons, though she increased it slightly in Autumn (Figure 26).

The home range area for Hati in Winter was almost two and half times larger than that occupied in Spring. Similarly, the home range area for Tommy in the Spring was almost two and half times larger than that for Winter. Also, the Winter home range area occupied by Tina was almost 6 times that occupied in Spring. However, these variations might be due to the fewer number of locations obtained on these cats for those seasons with smaller home range areas.

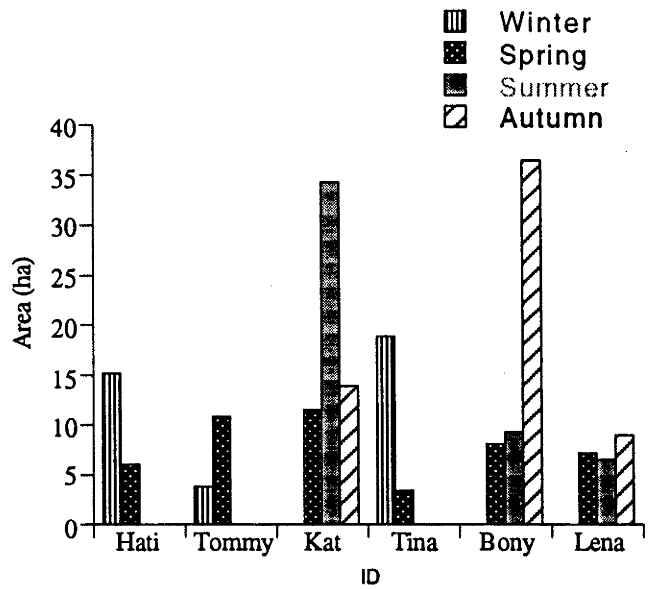

Figure 26. Seasonal home range areas for cats trapped at the ANU.

6.6.2. Seasonal overlap

Overlap between home ranges of cats radio-tracked at the ANU for different seasons are shown in Figures 27-30. Radio locations were obtained on only three cats (Tommy, Tina and Hati) in Winter, and overlap occurred between home ranges for Tina and Hati. Only 2.9% of Tina's home range overlapped with 3.7% of Hati's home range and represented an area of overlap of 0.56 ha (Figure 27).

During Spring, locations were obtained on all six cats. Only 2.9% of Kat's home range overlapped with 9.4% of Tina's home range, and represented an area of overlap of 0.33 ha. However, no overlap occurred between the home range for Tina and that for either of the other four cats. In contrast, 93.5% of Bony's home range overlapped with 65.4% of Kat's home range, representing an area of overlap of 7.6 ha, while 45.8% of Lena's home range overlapped with 29.3% of Kat's home range, and represented an area of overlap of 3.4 ha. However, there was no overlap between the ranges of female cats and those of the other male cats (Tommy and Hati). No male-male overlap was observed between the home ranges. However, with the exception of Tina's home range, considerable female-female home range overlap was observed (Figure 28).

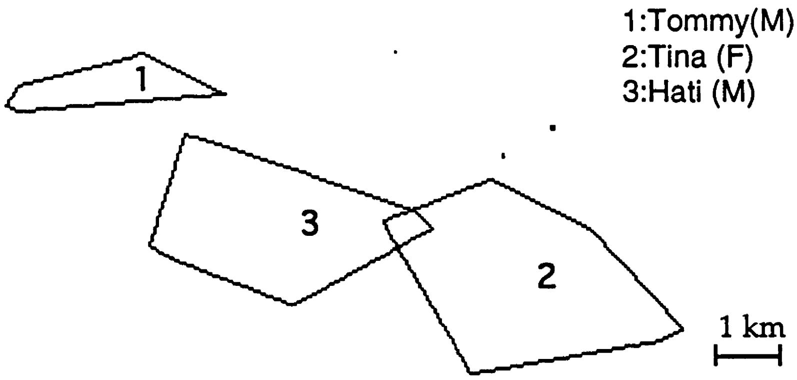

Figure 27. Overlap between home ranges of cats at the ANU in Winter.

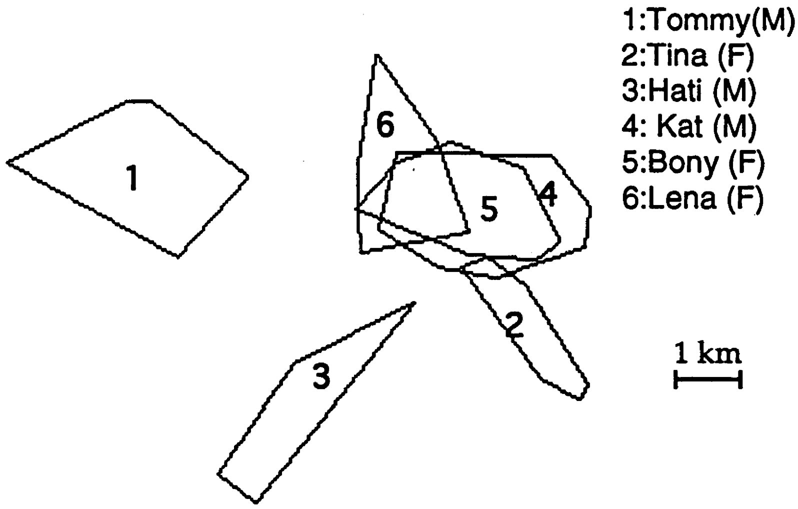

Figure 28. Overlap between home ranges of cats at the ANU in Spring.

In Summer, radio-locations were obtained on only 3 cats; Kat, Bony and Lena. There was little female-female home range overlap. However, considerable male-female home range overlap occurred. Almost the whole range for Bony (98.8%) overlapped with 27.2% of the home range for Kat, and represented an area of overlap of 9.3 ha, while, 79.4% of the home range for Lena overlapped with 15.5% of the home range for Kat, and represented an area of overlap of 5.2 ha. Also, overlap was observed between the home ranges of the three cats radio tracked at the ANU (Figure 29).

Similarly, in the Autumn, only 3 cats; Kat, Bony and Lena were radio-tracked at the ANU and considerable overlap occurred between the home ranges for the three cats (Figure 30). Less than 20% of the home range for either Bony and Lena overlapped with the home range for Kat. However, 47.6% of the home range for Lena overlapped with 11.9% of the home range for Bony, representing an area of overlap of 4.3 ha.

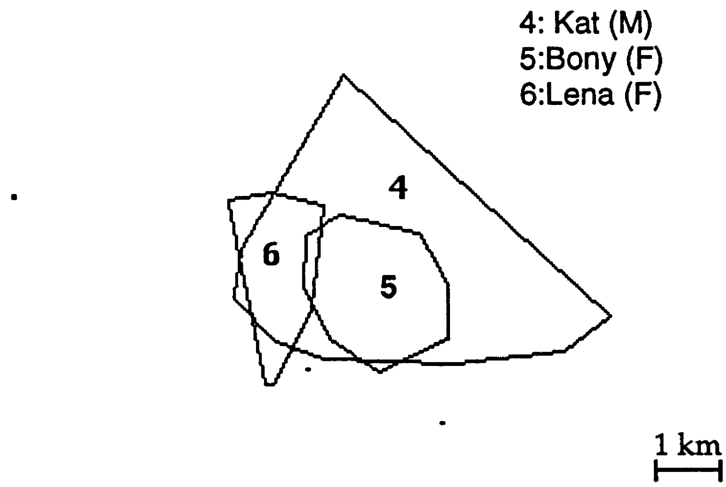

Figure 29. Overlap between home ranges of cats at the ANU in the Summer season.

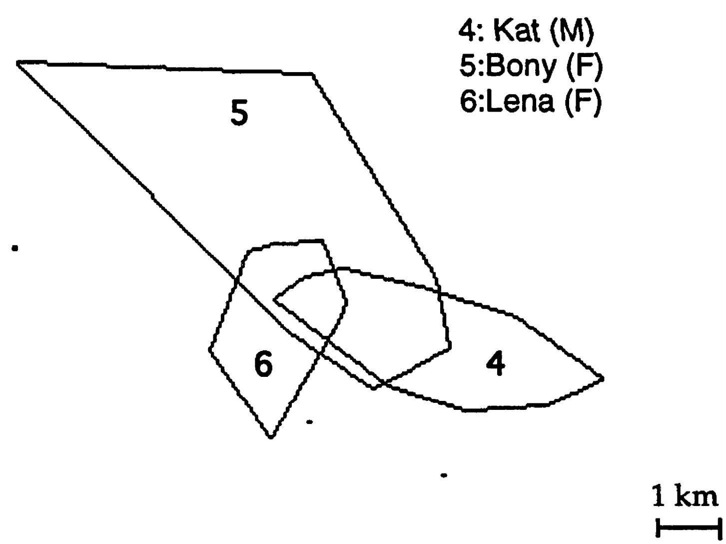

Figure 30. Overlap between home ranges of cats at the ANU in the Autumn season.

CHAPTER 7. HOME RANGE, BEHAVIOUR AND ACTIVITY DISCUSSION

7.1. Home range

7.1.1. Area

The method used in the compilation of home range areas is likely to lead to over estimates, because some excursion areas that might have been visited only once are included by the convex polygon method.

With the exception of Bat, for whom very little can be said, all radio-tagged cats maintained home ranges, and within each home range, particular areas were favoured. These were areas that provided shelter, like the spaces under buildings, drainages, and behind bushes. Such areas were used mainly as daytime refuges. Tina and Lena preferred spaces behind thick bushes, occasionally moving to spaces under buildings. Bony, Kat and Tommy preferred sheltering in the spaces under buildings, while Hati mainly preferred drains. At times when cats were very active, they visited feeding places within the home range at least once every day. These mainly included the garbage bins around public eating places and students' residences.

The home range area of most of the cats radio-tracked at the ANU was reliably estimated, but those of some cats on which few locations were obtained could have been underestimated.

Individual differences in home range size were apparent. However, unlike what has been reported for most studies (Dards 1978; Macdonald and Apps 1978; Jones and Coman 1982; Konecny 1983; Warner 1985; Fitzgerald and Karl 1986) that male cats have ranges larger than those of females, statistically, the home ranges for male and female cats were not significantly different. Despite the fact that the largest range area was for a female (Bony), the ranges for the other adult females were smaller than those for adult male cats.

Generally, the home range sizes obtained for the cats radio-tracked at the ANU were much smaller than have been found for feral cats in other studies (Dards 1978; Corbett 1979; Jones and Coman 1982; Konecny 1983; Fitzgerald and Karl 1986). However, as was the case for cats at Avonmouth Docks in the UK (Page *et al.* 1992), this may be due to the closeness and concentration of housing around the ANU, hence yielding an abundance of food. The cats at the ANU were receiving auxiliary feeding, scavenging, and also, to a lesser extent, catching some food. The abundance of food at the ANU and the neighbouring public eating places could have resulted in reduced need to hunt for food, hence the small home range sizes obtained.

7.1.2. Overlap between home ranges

As was found at Portsmouth dockyards (Dards 1978; 1983), at the ANU all female cats held overlapping home ranges and, with the exception of Tommy, male cats had ranges that overlapped with those of female cats.

Though considerable range overlap was found for females, no contact was observed between them. Although overlapping home ranges were occupied by the female cats, hunting/foraging grounds might have been shared with neighbouring cats, which hunted solitarily, as was found by Corbett (1978). Furthermore, female cats might have been avoiding each other by using overlap areas at different times. Page *et al.* (1992) argued that such areas may be shared spatially, but appear to be temporally discrete. This may be especially true for Bony and Lena as they were radio-tracked during the same period and for the same length of time. However, as these two were mainly radio-tracked after locations on Tina had stopped, there is not much evidence for or against the suggestion that Tina avoided Lena and Bony by using the overlap areas at different times.

The areas of overlap were areas that provided food, such as the garbage bins behind the student union, the residences, and the neighbouring public eating places. The female cats shared these feeding places, resulting in overlap in their home ranges. Since no contact between female cats was seen, the female cats radio-tracked at the ANU may have been solitary rather than group-living.

Male cats at the ANU maintained almost exclusive home ranges. There was very little overlap between the ranges for Tommy and Hati. Tommy was a kitten, and Hati could possibly have been his father, hence the overlap. Furthermore, the two cats shared an eating place, the garbage bins behind Caterinas shop. It may be that food was the factor attracting both cats to the same area of overlap. However, as Tommy was radio-tracked after Hati had shed his transmitter, much overlap and actual contact could have occurred, but went undetected.

There was very little overlap between the ranges for Tina and Hati and no contact was observed between the two cats. These two cats may have shared the small area of overlap spatially, but not temporally. The reason for the overlap between the home ranges may have been the common eating place, as the two cats were separately seen feeding near the garbage bins behind Caterinas Shop, next to the Law School, and the garbage bins behind University House. The overlap area may represent a common feeding ground used by both cats, but at different times.

Tommy was a recapture when radio-tagged. Although there was no range overlap between the range for Tommy and that for Tina, the first time Tommy was trapped, during the trial trapping sessions, he was caught within Tina's home range, next to another female cat. More locations were needed on Tommy during the same period that Tina was radio-located, to detect any overlap between the home ranges that might have occurred.

During the time Tommy was radio-tracked, he was mostly seen moving with the same female uncollared cat. Also, Hati was seen once seated next to another uncollared cat. Therefore, although little overlap was found between the ranges for Tommy and Hati and those for other cats, these two males associated with other uncollared cats. The apparent lack of overlap of home ranges of these two cats over a number of seasons, may be a result of the number of position-locations that were identified during the period of radio-tracking. The problem arose because Tommy was radio-tracked after Hati had shed the radio-transmitter, therefore, any additional overlap between their ranges would have gone undetected. The overlap area was due to a common feeding place, as these two cats were seen on separate occasions feeding near the garbage bin next to Caterinas shop.

Generally, male cats maintained exclusive home ranges, perhaps reflecting territorial behaviour. However, no territorial behaviour such as urine spraying, was observed. Considerable overlap of ranges occurred between cats of the opposite sex. The home range of Kat overlapped with those of the other females. However, there was little overlap between the ranges for Kat and Tina, most probably because most of the locations on Kat were obtained after Tina had disappeared.

There was considerable overlap between the range for Kat and those for either Lena and Bony. Furthermore, actual contact was observed between Kat and these two females. Kat was found seated next to either Lena or Bony on several occasions, at late hours of the night. Therefore, Kat might have had both Lena and Bony as mating partners and may be the father of both Lena and Bony's kittens. Other than mating, Kat shared feeding places with both of these two females. So, the overlap areas were probably used for feeding and mating activities, especially for Lena. Kat and Bony also shared the same shelter facilities. Both cats were found on separate occasions in the spaces under buildings at the ANU, where they seemed to spend most of the day. The overlap between the home range for Hati and those for either Tina and Lena was probably due also to sharing the same feeding places.

7.1.3. Home range use

The overall range area determined for each cat may have been big, but the cats had core areas within their home ranges where they spent most of the time. These were invariably areas that provided shelter and food. Lena was found on most occasions behind bushes where she spent the day and any other times at night when she was not hunting for food. However, she used several different bush patches within her home range, venturing from such areas to feed at night. In Autumn, however, Lena occasionally ventured out of her normal home range with her kittens to a neighbouring public eating place to scavenge in the garbage bins.

Similarly, the resulting large range for Bony was due to the excursions she made out of her normal home range to neighbouring places with her kittens in search of more food in Autumn. However, for most of the time, Bony stayed in a small area of her entire range where she sheltered and obtained food. Much of her time was spent near buildings that had spaces below them. Such spaces were used as refuge during the day, when she was resting.

Kat utilised much of his entire home range. However, some of the area was due to excursions he made in Summer, when the ANU was in recess, to neighbouring public eating places in search of food, and to a neighbouring suburb possibly in search of mates, since on one occasion during radio-tracking at night, he was found seated next to an uncollared adult cat in a neighbouring suburb, Turner.

Generally, these three cats (Kat, Bony and Lena) spent most of their time in small areas within their home ranges, venturing out to make excursions to neighbouring places in search of food and mates.

Hati, Tommy and Tina spent most of their time in very small portions of their entire range where they obtained food and shelter, occasionally moving to other places possibly in search of more food.

7.2. Seasonal variations

7.2.1. Area

Apparent variations in the home range area occupied by the cats at the ANU occurred, but were not statistically significant. Since few locations were obtained on Hati and Tina for the Spring season, and on Tommy for the Winter season, this might explain the variations in range size found for these cats. More meaningful conclusions on the seasonal variations in the home range size can be made only for the seasons when enough locations were obtained.

Contrary to what was found in most studies, that female cats reduced their home ranges when they had kittens, spending most of the time in a small area so as to look after the kittens (Jones and Coman 1982; Fitzgerald and Karl 1986), Bony and Lena instead increased their ranges. Lena occupied almost the same home range in Spring and Summer. However, in Autumn, she slightly increased her range size, occasionally venturing out of her normal range area, to the neighbouring Workers Club about 100 m off campus. Similarly, Bony occupied almost the same home range in Spring and Summer, but in Autumn, occupied an area almost four times as large.

Because of the possibility of reduced mammal prey availability in the cold Autumn season, cats might become increasingly commensal (Newsome 1991; Tabor 1981), taking mainly scraps and food handouts from people. Furthermore, there may be increased food requirements to feed the kittens. Therefore the home ranges for Lena and Bony may have increased in Autumn to obtain enough food. However, Lena and Bony spent most of the time in their usual home ranges occupied in all the three seasons, occasionally venturing away from these home ranges with their kittens to the Workers Club and other neighbouring places in search of scraps and food handouts.

Contrary to what was found for Lena and Bony, Kat occupied the biggest range area in Summer, when he made excursions to neighbouring areas, perhaps in search of food but probably mainly to mate with and defend females within his territory during that season. His home range in Summer covered that occupied in either Spring or Autumn, and it covered almost the entire range for Bony and three quarters of Lena's range. In both Spring and Autumn, Kat occupied a smaller home range. As most of the Summer falls within the holiday period at the ANU, the abundance of scraps in the garbage bins at the ANU may be reduced. Therefore, Kat may have increase his home range in search of scraps. As Autumn falls within the academic program at the ANU, There is a possibility of increased scraps in the garbage bins around the ANU. Therefore, Kat may have reduced his range area in Autumn, thus reducing his hunting efforts, moving into areas that offered the highest chance for food and provided good cover from the cold. This would contribute to less energy expended in keeping warm.

7.2.2. Overlap

Results for seasonal overlap showed that for Winter, overlap occurred between ranges for Tina and Hati, but Tommy's range did not overlap with that for either Tina or Hati. This might be because only a few locations were obtained on Tommy for the Winter season. Therefore any possible overlap may have gone unnoticed. The slight overlap reported for Hati and Tina's ranges may represent sharing of the same feeding place.

The range for Kat overlapped mostly with Bony's home range and less with Lena's range, mainly as Kat and Bony shared shelter, feeding places, and were possibly mates. However, Kat and Lena did not share shelter, but only shared feeding places, and may have possibly been mates too. Kat probably spent more time with Bony than with Lena. The little overlap found between the ranges for Kat and Tina probably arises from the few locations obtained on Tina at the same time as Kat was radio-tracked. On the other hand, it might be because Kat rarely visited the part where Tina mainly ranged, probably in search of food.

Tommy and Hati might have been territorial, hence the lack of overlap between their ranges and those for either Bony or Lena. It may, however, be that the few locations obtained on Hati for the Spring season resulted in some movements going undetected. However, female cats were not territorial and shared their ranges for food and mates.

Food availability and to some extent shelter were the common factors in the area of range overlap for cats radio-tracked at the ANU in Summer. At this time, the range for Kat encompassed almost the whole of Bony's range and almost three quarters of Lena's range. These cats shared the same shelter facilities, feeding places, and were possibly mates. However, only feeding places were shared and also, a possibility of mating partners may have resulted in the overlap observed between the summer ranges for Kat and Lena. However, as Kat and Lena did not share the same shelter facilities, this may have resulted in the lower overlap compared to that found for Kat and Bony's home ranges. Female cats shared the same feeding places hence the overlap observed between their ranges.

Considerable overlap occurred between the ranges of the three cats radio-tracked in Autumn, as they again shared the same feeding places, but used them at different times. However, little overlap occurred between the range for Kat and those for either Bony or Lena, possibly because the female cats increased their range areas, moving to neighbouring places with their kittens in search of food. The increase in their home range then resulted in the low percentage of overlap. As mating was over, the only factor common in the overlap area was food, and for Bony and Kat, also shelter. Female ranges overlapped considerably and again, food might have been the common factor in the area of overlap.

Generally, more overlap occurred in Summer than in the other seasons. The breeding season and search for mates may explain this. The cats were sharing partners and establishing territories, feeding places and also shelter facilities. As breeding activities are reduced in the other seasons, overlap between the ranges reduced. However, the cats still shared feeding places and shelter, therefore, overlap was still found between the ranges.

CHAPTER 8. GENERAL DISCUSSION

8.1. Discussion

8.1.1. Diet and food availability

Most literature (eg. Corbett 1978; Davies and Prentice 1980; Jones and Coman 1981a; Jones 1992) on the diet of cats suggests that cats are opportunist in their selection of prey and take prey which is most available at any given time. The occurrence of insects in the diet of cats supports the availability factor, as insect occurrence in the diet of urban cats, especially those at the ANU, increased in seasons when insects were expected to be very abundant. However, the vulnerability of the prey species also seems to be important. If a species is to be heavily preyed on by the cats, the vulnerable age groups should be readily available. Hence, abundance and vulnerability are important (McMurry and Sperry 1941; Eberhard 1954; Parmalee 1953; Coman and Brunner 1972; Jones 1977; Rose 1975; 1976; Taylor 1979; Jones and Coman 1981a; 1981b; Liberg 1984; Fitzgerald and Karl 1986; Catling 1988).

That vulnerability is an important factor determining predation by cats on a given prey species is illustrated by the differences in insect intake by cats from the two different environments (urban and fringe environments). Lighting in urban areas may increase the visibility of small sized insects to cats, hence increasing the vulnerability of the insects. At fringe sites lights are few. The concentration of insects around lights is important. It is far easier to catch something from a mass of insects, than from a scatter around the countryside. Sight may not be so important, that is, you are more likely to encounter a moth near a street light than if you are walking through the bush.

Previous studies on the diet of cats in the urban areas suggest that urban cats have a greater variety and availability of scrap food, both from hand outs and from food scavenged from garbage bins and left-overs around public eating places and picnic sites. Scraps may therefore comprise the most important source of food in the diet of urban cats (Tabor 1981; Dards 1981). Although cats in urban areas of the A.C.T may be commensal, scraps are of major importance only in certain seasons, coinciding with reduced availability of insects and vulnerable mammals.

Due to the concentration of scraps in the garbage dumped at the ML, scraps should provide an important food source for the cats at that site. Cats at MRC and GNR, however, lack access to readily available household food scraps and food handouts. Indeed there was very little likelihood of cats at these sites taking scraps in their diet. These cats must depend mainly on hunting as the main source of food, and hunted prey should therefore prevail in the diet of such cats.

If the degree to which the cats are feral is to be based on what an animal eats, the importance of scraps in the diet of cats from different sites may help decide whether such cats are truly feral, semi-feral or domestic. Taking this to be the case, it could be said that urban cats are not truly feral, but could have been semi-feral or domestic. Also cats at ML were not truly feral, whereas cats at MRC and GNR were truly feral.

Taking what an animal eats solely as a final parameter of whether an animal is feral or not may be misleading. Considering ML, the increased concentration of scraps in the garbage dumped at the site resulted in the cats having scraps as the most important source of food. Labelling such cats as not truly feral may be wrong as these cats may have no other direct contact with humans at all, but rely on hunting for their own food, in this case the easily available prey, the scraps. By contrast, there is enough evidence to support the idea that urban cats are not truly feral but commensal, since, in addition to scavenging from garbage bins and public eating places, they received food handouts from people.

Apart from food that may be present due to human activities, Dards (1981) argued that all the non-human fauna (except dog) are potential food for cats. On certain occasions during radio-tracking, a cat was seen chasing a rabbit. However, at other times, a cat would be seen seated near an adult possum, and there was no sign of fear and thus need to run away from either animal. Therefore, the fact that mammals occurred in the diet mainly during the breeding season of these mammals when young ones should be common, seems to agree with the suggestion made by previous studies (McMurry and Sperry 1941; Eberhard 1954; Parmalee 1953; Coman and Brunner 1972; Jones 1977; Rose 1975; 1976; Taylor 1979; Jones and Coman 1981a; Jones and Coman 1981b; Liberg 1984; Fitzgerald and Karl 1986; Catling 1988), that abundance coupled with vulnerability may influence the intake of mammals by cats.

Since increased mammal intake by the urban cats occurs during the break period of the ANU academic program, when scraps in garbage bins are likely to be reduced, and availability of vulnerable mammal age groups is likely to be on the increase, the results also agree with the argument put forward by previous studies (Corbett 1978; Davies and Prentice 1980; Jones and Coman 1981a; Jones 1992) that cats are opportunist feeders.

Cats from fringe areas rely primarily on hunting for their own food, so that, probably, a different picture would be painted, with increased occurrence of mammals in the diet of cats in different seasons, especially during breeding seasons. However, sampling of the cats' diet at these sites was insufficient over the seasons for more meaningful conclusions to be made.

As variability in the diet of cats seems to be influenced by the abundance of the prey species in question, seasonal fluctuations in the abundance of a given prey species might be reflected in the diet of such cats. Conversely, increased prevalence of a given species in the diet might indicate increased abundance of such a species. The breeding cycle of prey species and availability of vulnerable age groups for the mammals seem to determine the intake of such species, as is the case for insects. Similarly, abundance seems to determine cats' intake of scraps and this, especially for the ANU, seems to depend on the presence of undergraduate students at the ANU.

For the urban cats, as suggested by previous studies (Newsome 1991; Tabor 1981), where seasonal fluctuations and reduction in abundance of mammals and insects occur, cats may become increasingly commensal between seasons. At the ANU, in Winter, cats also feed on carrion to some extent. From the results of prey abundance for cats at the urban sites, there appears to be a trend in the increase in abundance of prey species relative to their breeding seasons. However, monitoring of prey populations was not attempted over a long enough period for meaningful conclusions to be reached.

Contrary to popular opinion, results of the study of the diet of cats in the urban areas agree with the findings of Coman and Brunner (1972) that birds are a minor component in the diet of cats. This may be due to the availability of scraps, resulting in reduced need for hunting the difficult-to-catch birds. However, significant predatory impacts on birds are likely to be felt at the fringe sites, where there is a high likelihood of nestlings that may be easy to catch. Since the fringe cats rely mostly on hunting for their own food, the increased hunting efforts by these cats as compared to urban cats may result in more captures of birds from the fringe sites.

8.1.2. **Home range**

Results of the home range study for cats at the ANU support the definition of home range put forward in previous studies (Burt 1943; Jewell 1966) as their home range and movements seemed to be determined by the distribution of food, shelter, and the presence of other cats.

Previous studies have indicated that adult male cats occupy larger home ranges than adult females (Bailey 1974; Dards 1978; Macdonald and Apps 1978; Corbett 1979; Liberg 1980; Jones and Coman 1982; 1983; Konecny 1983; Warner 1985; Fitzgerald and Karl 1986). Consequently, predation impacts of adult male cats are likely to be spread over a wider area than those of adult female cats. However, results for the home range of cats at the ANU deviated from the popular view, with no significant difference between the range size for male and female cats. This may be because of the plentiful supply of food around the ANU. These cats shared feeding places, though they may have been using them at different times. Furthermore, male cats did not have to travel far to look for mates, since in some instances they shared the same shelter.

It has been suggested that an abundance of food in the form of scavenged material and food handouts may result in reduced need for hunting, hence reduced need for a large home range (Tabor 1981; Langham and Porter 1991). Changes in the quantity or location of available food may also result in changes in the size and shape of the home range of a given animal. Cats may change the use of an area, concentrating in areas where food resources are concentrated, or making excursions to such areas quite often. Changes in the home range of Kat was consistent with changes in food distribution. When undergraduate students were present at the ANU, there was an abundance of scraps in the garbage bins around the ANU. Cats therefore maintained their normal ranges at the ANU, feeding mainly from the garbage bins, with occasional hunting. During the breaks in the academic program at the ANU, the reduced abundance of scraps in the garbage bins resulted in Kat breaking out of his usual home range and feeding places, moving to neighbouring places in the city to scavenge in garbage bins around public eating places.

Previous studies argue that female cats with kittens occupy a smaller range than otherwise, spending much of their time on caring for and protecting the young ones (Dards 1978; Jones and Coman 1982; Iwamoto *et al.* pers. comm. via A. Newsome, CSIRO; Fitzgerald and Karl 1986). Where food is scarce, females would be expected to occupy a bigger range since they have to obtain food for themselves and the kittens. This seems to apply to the female cats with kittens at the ANU. With the increased need to forage further afield to procure food for the kittens, and the presumed reduced availability of mammal prey, these female cats increased their ranges from the normal ones occupied when without kittens, moving at night with their kittens to neighbouring public eating places, in search of food. They returned after feeding to their usual resting places in their normal ranges.

In urban areas, the distribution of garbage bins, public eating places and picnic sites comprise areas of overlap in home ranges. Also, the increased availability of buildings with spaces under them provide good shelter conditions for the cats and may attract many cats. This may result in cats being communal, and they may be male and female, hence reducing the need for males to range far in search of mates.

Radio-tracking revealed that cats were most active at night, spending the day in one place, usually in spaces below buildings, behind bushes, or sometimes in drains. Therefore at such times, since very little insight could be gained into the movements of such cats, determination of home ranges based on day time locations only would be misleading.

8.2. Conclusions

Generally, the results of the diet study for cats in the Australian Capital Territory portray cats as opportunist predators. The major food components in any given season are items that are seasonally abundant. Also, the availability and ease of capture seems to influence the choice of prey that cats are taking.

Prey availability is the main determinant of which prey species will be taken by cats in the A.C.T. However, abundance of a species alone may not heighten cats' predation on it. For this to occur, abundance must be coupled with vulnerability. For small prey species, availability may be the determining factor, whereas for bigger, more aggressive, prey species abundance of vulnerable age groups may be the main determining factor. In such a situation, the breeding season for large prey may be important in determining cats' predation on such species.

Since increased intake of scraps and food handouts by cats in the urban areas is likely to occur in the cold seasons (Winter and Autumn), any control measures that will employ the use of toxic baits are likely to be most successful during such times.

The diet study gave an indication of prey species important to cats in the A.C.T, and possible conditions for their intake by the cats. This, when deciding possible management strategies, will help determine which species are at greatest risk due to cat predation.

No endangered species have been identified in the diet of A.C.T cats so far and the species that have been identified are similar to those found in other studies (Coman and Brunner 1972; Fitzgerald and Karl 1979). Although some endangered bird species may be taken by these cats, bird remains were not identified to species. The high rate of predation of possums could affect possum numbers in the longer term.

For the urban cats, the abundance of garbage bins and public eating places, refuse and handouts in the form of cat food, sardines and milk provide a sure and fairly reliable food supply for the cats in the urban areas. So many food handouts are available, especially at OPH, that sometimes food remains uneaten for two or three days. The old people in the urban areas providing these food handouts feel it is their duty to look after these cats and to protect them. The more food they provide for the cats, the more they are likely to attract other cats, hence the more likely is the population of such cats to increase rapidly in such areas.

Although the scraps and food handouts may not be available always, they probably support cat populations at higher levels than otherwise. As long as their supply remains in abundance, cat colonies in the urban areas will remain. Furthermore, the garbage bins in most public eating places and picnic sites have no lids and are shallow enough for the cats to jump in, eat what ever they can and jump out again. Control measures should therefore consider management strategies that will minimise the chances of cats scavenging from the garbage bins by ensuring that such bins have secure lids that are tightly fitted at all times. Minimising the food handouts for cats in the urban areas will also reduce the food available for such cats and help to control their populations. However, there is a danger that they may switch to other prey, possibly more endangered species. The introduction of bins inaccessible to cats is already occurring in the A.C.T. A study of their effect on cats and cat prey populations seems timely.

The home range and movements of the urban cats seem to be influenced mainly by the distribution and abundance of food and also shelter. Cats may shift their home range any time there is a change in food distribution. However, if food is so scarce that the available food in the small range to be occupied cannot sustain the cats, these cats may increase their ranges, foraging over a bigger area. Therefore, food availability will be the determining factor of the home range size occupied by the cats.

For effective control measures using toxic baits, placing the baits in areas near the garbage bins would increase the chance that cats would take the baits. The baits would also have to be put out just before the late evening-early night hours (7:00 pm-11:00 pm) to ensure that cats find the baits when they visit their feeding places.

It appears that, at least in my urban study sites in the A.C.T, the cats may be wrongly accused of having a significant effect on the native wildlife. There is little indication of native species in their diet. Since increased intake of mammals seems to occur in the seasons when such species are likely to be abundant, cats might just be taking the excess of the populations of such species. However, more sampling of the diet of cats in the fringe areas ought to be carried out over a number of seasons for more meaningful conclusions to be reached.

8.3. Recommendations for further research

Although the present study revealed likely trends, a much larger sample of cats and their diet is needed. This study was unable to determine the movements and home ranges for cats at the fringe sites. Also, seasonal variations in the diet of cats at the fringe sites were not determined. Therefore future research on the cats in the A.C.T should consider detailed studies of the diet and movement activities of cats in the fringe areas over a number of seasons. This will help to ensure much more meaningful comparisons of the impact of cats on the native wildlife in the A.C.T by the urban and fringe cats.

To accurately assess the impact of cats on the native wildlife, in addition to determining the diet composition of cats, the population of the prey species being taken by such cats should be determined over a number of seasons. This will help determine the likely impact of the cats on the given prey species, by comparing the cats' intake of a given prey to the population of that prey. Determining the seasonal diet of cats and the population of the prey species will help to determine whether the cats are behaving as opportunist feeders, taking prey when it is most abundant. Determining the age composition of the prey population, then relating this to the diet composition of the cats, will give insight into the possible reasons for the cats taking that prey and to their potential impact on the prey. For example, if they catch pregnant females, it will have a greater impact than if they catch juveniles.

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Appendix 2. A questionnaire for the preliminary survey of cats in Canberra.

There is growing concern about feral cats and their impacts on the native wildlife in the ACT. It is believed that feral and stray cats have a significant effect on the wildlife population of the Territory. However, little research has been carried out to assess the impact of feral cats on the native species. I am Elizabeth Kunihira, a student at the Australian National University. I am doing some work on the feral and stray cats in parts of the ACT. The project is supported by ACT Parks and Conservation office. The research methods intend to be used are non destructive and will not inflict pain on the cats. Your assistance is earnestly requested by providing information on the cats in this area. Following is a list of questions which I would like you to answer in order to provide us a preliminary idea in designing and conducting the research. Please feel free to provide any other information on cats in the area which you might have and believe is important to the research.

1. Location: Street Name ______________________________

   Suburb ______________________________

2. Have you observed cats in your area? ☐ Yes ☐ No
3. How many cats have you observed in the area in a day? __________
4. In which places are they mostly seen? Please check
   - ☐ In the streets
   - ☐ In my lawn
   - ☐ My Neighbor's lawn
   - ☐ Business/shop area
   - ☐ Rubbish tips
   - ☐ Others (Please specify) ______________________________
5. Please specify the activity of the cat, for instance, was it
   - ☐ Feeding
   - ☐ Sleeping
   - ☐ Moving around
   - ☐ Others (Please specify) ______________________________
6. At what time of the day do you notice them to be most active? ______
7. Where do you think they come from? ______________________
8. Do you ever feed them? ☐ Yes ☐ No
9. If yes, how frequently? ☐ times per day ☐ times per week
10. What do you feed them with? ______________________________

Appendix 3. Prey items in the diet of cats at the Australian National University (ANU). (Total number of scats = 266).

MAMMALS	Rodents:	Rats;	Bush Rat
			Black Rat
		Mice	House Mouse
	Rabbits		
	Possums:	Brushtail Possum	
		Ringtail Possum	
	Glider		
	Fox		
	Kangaroo		
REPTILES			
BIRDS			
INSECTS	Moth		
	Beetle		
	Elytron		
	Butterfly		
	Cicada		
	Fly		
	Ants		
	Cockroaches		
	Grasshopper		
	Spider		
	Bee		
PLANT MATERIAL	Grass		
	Sticks		
	Leaves		
HOUSEHOLD SCRAPS			

Appendix 4. Prey items in the diet of cats at Old Parliament House (OPH). (Total number of scats = 130).

MAMMALS	Rodents:	Rats;	Bush Rat
			Black Rat
		Mice	House Mouse
	Rabbits		
	Possums	Brushtail Possum	
		Ringtail Possum	
REPTILES			
BIRDS			
INSECTS	Moth		
	Beetle		
	Butterfly		
	Fly		
	Ants		
	Cockroaches		
	Grasshopper		
PLANT MATERIAL	Grass		
	Sticks		
	Leaves		
HOUSEHOLD SCRAPS			

Appendix 5. Prey items in the diet of cats at Mugga Lane rubish dump (ML). (Total number of stomach samples = 14).

MAMMALS	Rabbits:		
	Rodents:	Mice;	House Mouse
	Possums:	Ringtail Possum	
INSECTS	Beetle		
	Unidentified		
HOUSEHOLD SCRAP			
PLANT MATERIAL			

Appendix 6. Prey items in the diet of cats at Googong Nature Reserve (GNR). (Total number of stomach samples = 11).

MAMMALS	Rodents:	Rats;	Black Rat
			Bush Rat
		Mice;	House Mouse
	Rabbits		
BIRDS			
INSECTS	gryllids		
	mantids		
	moth		
	grasshopper		
	unidentified		
PLANT MATERIAL	grass		
	sticks		
	leaves		
MISCELLANEOUS			

Appendix 7. Prey items in the diet of cats at Murrumbidgee River Corridor (MRC). (Total number of stomach samples = 15).

MAMMALS	Rabbits	
	Possums:	Ringtail Possum
	Kangaroo	
BIRDS		
INSECTS	Gryllid	
	Dragonfly	
	Unidentified	
PLANT MATERIAL	grass	
	sticks	
OTHER ITEMS	cat fur	
MISCELLANEOUS		

ul

APPENDIX 1 MAP OF THE AUSTRALIAN NATIONAL UNIVERSITY

PARK : A4_CARPARKING-A
ANU94/S/4831

SCALE : 1 :7000
PLOTTED ON 12-DEC-1994

DRAWN : LINO FIORESE